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DEVELOPMENT OF THE ALVEOLAR ARCHES IN NORMAL AND ABNORMAL OCCLUSION

BY MARCUS S. GOLDSTEIN AND FREDERICK L. STANTON

Division of Child Research, New York University College of Dentistry

IN A previous paper we have presented evidence on the mean growth in the alveolar arches (Goldstein and Stanton, '35), but in view of the inadequate series for the purpose at the time, the relationship of development with dental occlusion was not considered.[1] Sufficient material is now available to us for examination of this latter question. Moreover, the method of treatment will be different in that the development of the arches as it occurs in the same individual will be our prime concern. In brief, it is the purpose of the present contribution to answer, to the best of our ability and with the material at our disposal, the following questions: (1) In a sample of the population, segregated according to age and type of dental occlusion, how many of the subjects from one year to the next manifest increment, decrement, or neither, in the various sections of the alveolar

[1] Dental occlusion is "the relationship of the teeth of the maxilla and mandible when the jaws are closed and the condyles are at rest in the glenoid fossae." Normal occlusion referred to dentitions in which the "cheek" teeth (canines and teeth posterior thereto) were anatomically in correct occlusion and the surface-to-surface contact of the incisors was not, or only slightly, broken; any appreciable deviation from these conditions was considered abnormal or mal-occlusion.

arches? (2) How great in amount is this increment or decrement in the individuals manifesting either? (3) Is there any difference in the absolute dimensions and form of the alveolar arches of subjects with normal occlusion and those with various types of abnormal occlusion?

MATERIAL AND METHOD

The material includes observations on 285 children (154 males, 131 females), ranging in age between 2 and 12 years. These children are the same as reported upon in our previous study already referred to and the details relevant to their ethnic composition may be found therein. It will suffice in the present instance to state that they are all white and of native birth.

Dental impressions in plaster were taken on the children at yearly intervals. It is obvious that a single observation on developmental behavior of the alveolar arch involves two dental casts of the same individual. Many children had been under observation for a period of 3, 4, and 5 years, although most of these latter children were not of the same age to begin with.

Measurements were taken on projections (five times enlarged) of the casts. The landmarks of measurement were the centers of the teeth at the alveolar margin, except width and length of arch. The buccal aspects of the deciduous second molars are the landmarks for the width diameter, the measurement being the greatest distance between the right and left sides. Length of the arch is the distance from the labial aspect of the central incisors (at alveolar margin) to the middle of a line drawn between the distal ends of the deciduous second molars (at alveolar margins).[2]

Classification of occlusion was made by the second author, the usual orthodontic criteria being employed in this determination.[3] The Class

[2] The diameters observed were as follow. Widths: C-C, between canines; D-D, between deciduous first molars; E-E, between deciduous second molars; 6-6, between permanent first molars; total width, as indicated in text above. Lengths: (anterior, A-C), from bisection of a line between central incisors to middle of line drawn between centers of canines; (posterior, C-E), from middle of line between centers of canines to bisection of line between centers of deciduous second molars; total length, as indicated in text above.

For details of method of projection of cast, see Stanton, *et al.*, '31.

[3] The classification of "abnormal" occlusion stems from Angle (1907), and is based on the anatomical mesio-distal relationship of the maxillary and mandibular side teeth (canine and teeth posterior thereto), his criteria being as follows:

I was broken up into a group distinguished by excessive overbite of the incisors, horizontally and vertically (indicated as Class I A). This group comprises by far the major portion of the Class I category. Further subdivision of Class I into distinctive categories, e.g. open-bite of the incisors, cross-bite, etc., although desirable, was not feasible for lack of adequate series.[4] Indeed, a combination of all cases in Class I other than those with excessive overbite (indicated as Class I B) was still not sufficient for detailed analysis and is given merely as a matter of record. The available material on Class III was entirely inadequate and is not considered. Even Class II is not well represented, although it must be remembered that this type of malocclusion is relatively infrequent, certainly much less common than is the Class I.

It also would have been desirable to consider the data with reference to sex, but the resulting limited series after subdivision of the material with regard to dental occlusion, made this step, regrettably enough, impractical. We may say, however, after mulling over the data, that the only substantial difference between the sexes perceptible to us was a somewhat sharper spurt of growth in the widths of the arch in the females at 5-6 years of age; the increment in the males also rises at this time but apparently not as definitely as in the females.

A word is due with regard to definition of the terms Increment, Decrement, and Neither. In many cases the measurement of a dimension was exactly the same one year after the first examination, the difference therefore being a flat zero. Not infrequently, however, the difference was 0.1 or 0.2 mm., plus or minus, an amount scarcely perceptible to the naked eye. The thickness of a line or magnitude of a dot, as well as the possibility of error either in projection of the cast or in

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Class I, all disturbances in the dental alignment *not* involving the aforementioned mesio- distal relationship of upper and lower teeth, or involved to a limited extent—up to and including an edge to edge contact of maxillary and mandibular cusps instead of the normal cusp and fossa or groove relationship; Class II, the mandibular side teeth being in distal relationship to the corresponding maxillary teeth; and, Class III, the mandibular side teeth being in mesial relationship to the corresponding maxillary teeth.

[4] The "bite" refers to the kind of interrelationship of upper and lower teeth in local sections of the dental arch. Excess overbite, for example, refers to the anterior of the arch, specifically describing the condition where the upper incisors excessively protrude horizontally beyond the coresponding lower teeth, and/or the upper central incisors excessively overlap the lower incisors. Both excess "horizontal" and "vertical" overbite usually occur together.

mensuration, even if very slight, could easily result in a difference of 0.1 or 0.2 mm. Hence, these figures were considered negligible and counted with zero, as indicating neither increment nor decrement; they were not, moreover, included in the computations of the several average increments or decrements. The smallest amount taken as appreciable was ± 0.3 mm.

WIDTHS OF ARCHES

Maxilla. Table 1 and Figure 1 refer to conditions in the width of the maxillary alveolar arch. The table gives the amount of increment or decrement occuring during a period of one year in the same individuals; the figure graphically portrays the percentage of subjects manifesting increment, decrement, or neither, during one-year intervals. Both table and figure are complementary.

Age intervals represented by too few cases were omitted from the graph.

Several broad and significant facts are discernible in the data. Perhaps most important is the positive assurance that, between 5 and 8 years and particularly during the 7-8 year interval, there will be in all sections of the arch and in all the types of occlusion considered, a greater or less *increase* in the widths of the alveolar arch *in the preponderantly major proportion of children.*

Also of definite interest is the indication that during the period of one year an appreciable number of cases manifest decrement; as well as the fact that in a relatively large number of the subjects neither increment nor decrement, but stability, occurs. Both of these phenomena are apparent in all the widths of the deciduous arch and in the several types of occlusion, although varying in incidence of occurrence as a result of these factors.

Regarding the factor of occlusion, it is clear, as already intimated, that the perceptible differences are ones of degree rather than of kind. Subjects with malocclusion, as those with normal occlusion, manifest increment, decrement or stability in the width of the arch. On the other hand, it would seem that malocclusion is more or less differentiated from the normal, particularly in the early years (3-5), to the extent that a greater proportion of cases in the Class I (A) category manifests increment, while in Class II malocclusion a relatively larger number exhibits decrement, each as compared with conditions in normal occlusion. Regarding rate of development, whether increment or decrement, the

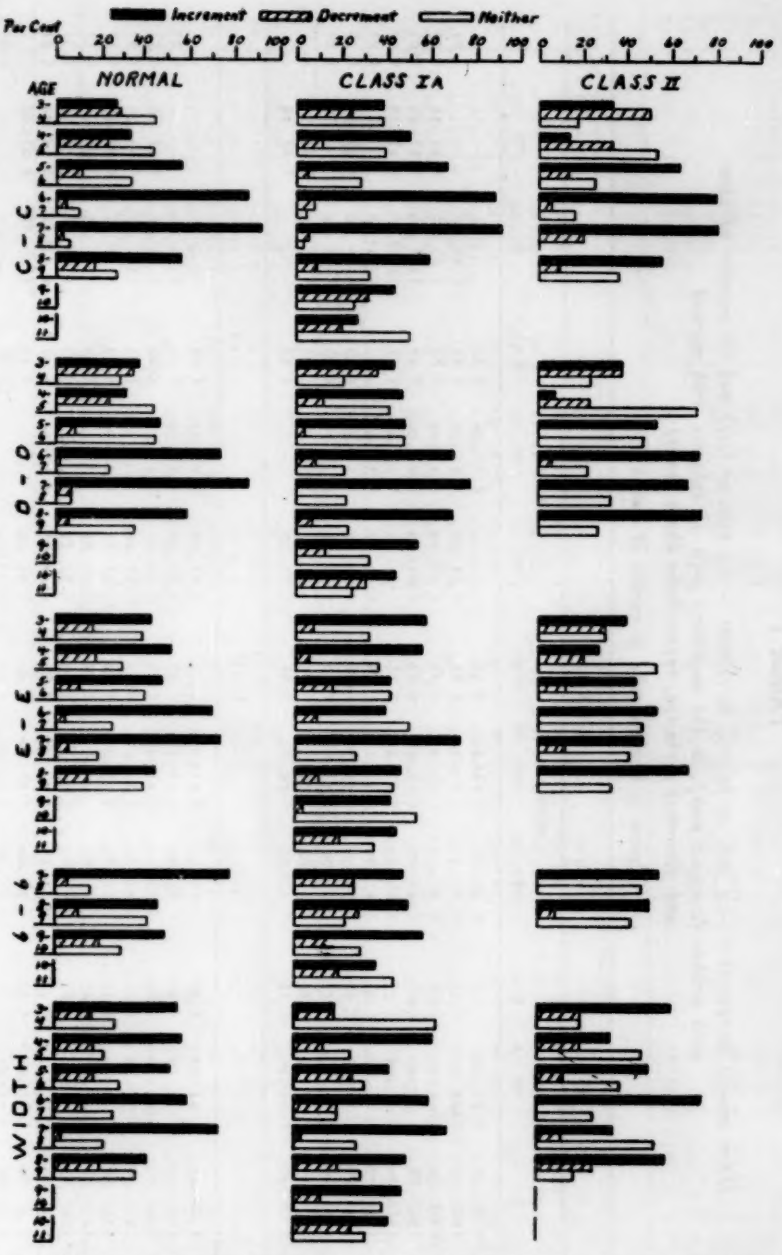

FIG. 1. MAXILLA: PERCENTAGE OF CASES MANIFESTING INCREMENT, DECREMENT, AND NEITHER, RESPECTIVELY, IN THE WIDTHS OF THE ALVEOLAR ARCH AT ANNUAL INTERVALS AND ACCORDING TO TYPE OF DENTAL OCCLUSION

TABLE 1

Mean annual increment (+0.3 mm. or more), decrement (—0.3 mm. or less) and the number of cases with neither (0.0±0.2 mm.), in the maxillary arch of subjects with normal and abnormal occlusion, respectively (both sexes)

(Figures in brackets refer to number of cases.)

C - C

AGE INTERVAL	NORMAL +	NORMAL —	NORMAL 0	CLASS I(A) +	CLASS I(A) —	CLASS I(A) 0	CLASS II +	CLASS II —	CLASS II 0	CLASS I(B) +	CLASS I(B) —	CLASS I(B) 0
2- 3	(1) .40	(2) .50	....	(2)1.15	(1)1.40	(3)	.....	(1) .40	(4)	.....	.....	....
3- 4	(11) .50	(12) .49	(18)	(6) .45	(2)1.15	(6)	(4) .57	(6) .51	(2)	(2) .50	.....	(6)
4- 5	(20) .53	(14) .51	(26)	(9) .51	(2) .55	(7)	(2) .70	(5) .44	(8)	(6) .70	(5) .54	(3)
5- 6	(34) .78	(7) .40	(20)	(14)1.07	(1) .60	(6)	(10)1.03	(2) .50	(4)	(13) .73	(1) .40	(10)
6- 7	(41)1.14	(2) .45	(5)	(22)1.33	(2) .45	(1)	(15)1.10	(1) .40	(3)	(16)1.06	(1) .70	(1)
7- 8	(29)1.16	(1) .60	(2)	(34)1.20	(2)1.10	(1)	(12)1.16	(3) .43	....	(15)1.16	.....	(4)
8- 9	(10) .88	(3) .40	(5)	(19) .99	(3) .70	(11)	(6) .55	(1) .40	(4)	(14) .80	(3) .90	(1)
9-10	(3) .60	(3) .56	(2)	(12) .70	(9) .67	(7)	(1) .30	(1) .70	(4)	(6) .73	.....	(2)
10-11	.....	.....	(4)	(4) .80	(3) .63	(8)	.....	(1) .40	(2)	(2) .95	(1) .90	....
11-12	(1) .40	(2)1.40	(1)	(5)1.12	(1) .60	(2)	(2) .45	.....	(1)	.....	(2) .35	....

D - D

AGE INTERVAL	NORMAL +	NORMAL —	NORMAL 0	CLASS I(A) +	CLASS I(A) —	CLASS I(A) 0	CLASS II +	CLASS II —	CLASS II 0	CLASS I(B) +	CLASS I(B) —	CLASS I(B) 0
2- 3	(2) .95	(1) .50	(3)	(6)1.00	(2)1.35	....	(1) .40	(2) .45	(2)	.....	.....	....
3- 4	(15) .55	(14) .55	(12)	(6) .41	(5) .68	(3)	(5) .58	(5) .52	(3)	(6) .73	.....	(2)
4- 5	(19) .64	(14) .50	(26)	(8) .53	(2) .45	(7)	(1) .40	(3) .33	(10)	(6) .61	(1) .60	(7)
5- 6	(27) .58	(5) .42	(26)	(10) .82	(1) .70	(10)	(8) .91	.....	(7)	(12) .58	(1) .40	(9)
6- 7	(33) .68	(1) .40	(11)	(16) .83	(2) .30	(5)	(13) .61	(1) .40	(4)	(14) .67	(2) .75	(3)
7- 8	(25) .78	(2) .45	(2)	(25) .85	.....	(7)	(10) .65	.....	(5)	(11) .75	.....	(5)
8- 9	(10) .64	(1)1.10	(6)	(21) .63	(2) .45	(7)	(8) .57	.....	(3)	(9) .60	(2) .75	(3)
9-10	(3) .60	.....	(4)	(13) .81	(3) .56	(8)	(2) .30	(1)1.10	(3)	(4)1.32	(1)1.50	(5)
10-11	(3) .60	(1)1.40	(1)	(7) .81	(5) .60	(4)	(1) .40	.....	(1)	(3) .86	(2)1.05	....
11-12	(3) .67	(1)1.30	....	(3) .46	(3) .56	(4)	.....	.....	(2)	.....	.....	(2)

TABLE 1 *(Continued)*

TABLE 1 *(Continued)*

E - E												
2- 3	.....	.....	(2)	(1) .70	(1)1.20	....	.....	.....	(2)	.....	.....	....
3- 4	(13) .63	(5) .42	(12)	(7) .52	(1)2.10	(4)	(4) .55	(3) .60	(3)	(7) .65	.....	(1)
4- 5	(31) .65	(11) .49	(18)	(9) .82	(1) .40	(6)	(4) .62	(3) .50	(8)	(8) .85	(2) .55	(4)
5- 6	(29) .59	(7) .58	(25)	(8) .72	(3) .40	(8)	(7)1.05	(2) .50	(7)	(15) .54	.....	(9)
6- 7	(33) .66	(2) .45	(12)	(8) .62	(2) .55	(10)	(10) .71	.....	(9)	(12) .77	(2) .35	(4)
7- 8	(23) .65	(2) .50	(6)	(21) .69	.....	(8)	(8) .58	(2) .40	(7)	(12) .72	(2) .50	(6)
8- 9	(9) .45	(3) .40	(8)	(14) .73	(3) .33	(13)	(8) .61	.....	(4)	(8) .48	(2) .80	(6)
9-10	(5) .62	(1) .40	(2)	(11) .72	(1) .90	(14)	(3) .66	(3) .30	(2)	(5) .76	.....	(5)
10-11	(3) .73	(1) .70	(2)	(9)1.20	(4) .32	(7)	(1) .80	.....	(2)	(3)1.43	(1) .50	(2)
11-12	(3) .70	(1) .40	....	(5)1.00	.....	(2)	.....	(1) .50	(2)	(1) .30	.....	....
Width												
2- 3	(1) .60	.....	....	(1)1.10	(1) .80	....	(1) .30	.....	(1)	.....	.....	....
3- 4	(16) .79	(5) .54	(8)	(2)1.10	(2)1.15	(7)	(6) .58	(2) .75	(2)	(6)1.15	.....	(1)
4- 5	(35) .80	(11) .53	(14)	(10) .94	(2) .40	(4)	(5) .48	(3) .60	(7)	(7) .98	(2) .45	(5)
5- 6	(32) .79	(11) .44	(18)	(8) .73	(5) .68	(6)	(8) .92	(2) .75	(6)	(14) .65	(2) .35	(8)
6- 7	(28) .75	(6) .50	(13)	(12) .59	(4) .37	(4)	(14) .66	.....	(5)	(12) .87	(2) .65	(4)
7- 8	(23) .73	(1) .40	(7)	(20) .87	(1) .40	(8)	(6)1.03	(2) .65	(9)	(11) .76	(4) .37	(5)
8- 9	(8) .57	(4) .57	(7)	(15) .79	(6) .45	(9)	(7) .71	(3) .50	(2)	(8)1.08	(2) .65	(7)
9-10	(4) .90	(2) .55	(2)	(12) .75	(3) .46	(10)	(3) .43	(3) .46	(2)	(3)1.26	.....	(7)
10-11	(3)1.20	(1) .90	(2)	(8)1.17	(5) .56	(6)	(1) .80	.....	(2)	(3)1.40	(2) .75	(1)
11-12	(3) .60	(1)1.10	....	(4)1.15	.....	(3)	(1) .40	(2) .40	....	.....	.....	(1)
6 - 6												
6- 7	(3) .56	(1) .40	(1)	.....	(2) .60	(1)	(3)1.00	.....	(2)	(3) .60	(1) .30	(1)
7- 8	(14) .77	(1) .50	(3)	(15) .70	(8) .68	(8)	(6) .95	.....	(5)	(9) .92	.....	(6)
8- 9	(9) .55	(2) .75	(8)	(20) .78	(11) .45	(9)	(6) .60	(1) .90	(5)	(6) .50	.....	(7)
9-10	(5) .84	(2) .40	(3)	(20) .68	(5) .44	(10)	(2) .45	(1) .40	(5)	(4) .87	.....	(6)
10-11	(4) .67	.....	(4)	(9) .51	(5) .82	(11)	(2) .80	(1) .30	(1)	(2)1.10	(1) .60	(2)
11-12	(4) .52	.....	....	(4) .85	(1) .30	(7)	.....	.....	(3)	(2) .40	(1)1.00	....

amounts are generally greater in malocclusion, especially in the anterior dimension (C-C), and in Class I (A) generally. In many instances, however, the amount of increment or decrement is practically alike in normal and the various forms of abnormal occlusion.

Mandible. Table 2 and Figure 2 refer to conditions in the widths of the mandibular arch. As in the maxilla, there is at the 5-6 year interval a definite spurt in the incidence of cases manifesting increment, increasing in intensity thereafter until at 7-8 years increment is by far the most common occurrence. This phenomenon prevails to a larger or less degree in all sections of the arch and in the several types of occlusion. In amount, too, the annual increment is generally highest between 5 and 8 years, being about one millimeter greater (or approximately double the rate) than in the preceding periods. The incidence of decrement and stability, especially the latter, is in each case relatively common between 3 and 4, and 4 and 5 years, sometimes even at 5-6 years.

With reference to section of arch, there is the suggestion that stability is definitely more common in the posterior regions of the arch than in the anterior segment (C-C). Indeed, the rate of increment, even decrement, tends to proceed at a more or less even pace both in normal and abnormal occlusion in the posterior regions in contrast to the sharp rise in the rate at 5-6 years, which is in turn continued to 8-9 years, in the C-C area, especially in normal occlusion. In amount the increment and decrement appear on the whole greater in the anterior width, although the differences are irregular and generally slight.

Also of interest is the approximately equal distribution of cases in Class I (A) during the early years (3-5) manifesting increment, decrement, and neither, as contrasted with the preponderance of stability at this same time in both the normal occlusion and Class II malocclusion groups. It might be pointed out that Class II appears especially prone to stability in the molar region (E-E). Also, that the rate of increment and decrement tends to be high in subjects with malocclusion as early as three years, especially in the anterior width.

TABLE 2

LENGTHS OF ARCHES

Maxilla. Tables 3a and 3b and Figure 3 concern the lengths in the maxillary alveolar arch. The picture is in startling contrast to that of the widths. Considering first the anterior segment (A-C), we note that normal occlusion is characterized by stability up to the 6-7 year interval

TABLE 2

Mean annual increment (+0.3 mm. or more), decrement (—0.3 mm. or less) and the number of cases with neither (0.0±0.2 mm.), in the mandibular arch of subjects with normal and abnormal occlusion, respectively (both sexes)

C - C

AGE (*Yrs.*)	NORMAL +	NORMAL —	NORMAL 0	CLASS I(A) +	CLASS I(A) —	CLASS I(A) 0	CLASS II +	CLASS II —	CLASS II 0	CLASS I(B) +	CLASS I(B) —	CLASS I(B) 0
2- 3	(2) .50	(1) .80	(2)	(5) .86	.....	(2)	(2) .60	(3) .43	....	.....	.....	....
3- 4	(9) .47	(9) .45	(24)	(5) .34	(4) .60	(5)	(2) .85	(3)1.30	(8)	(3) .66	(3) .53	(2)
4- 5	(16) .53	(15) .46	(29)	(6) .65	(5) .38	(7)	(2)1.05	(4) .52	(9)	(7) .76	(1) .30	(6)
5- 6	(31) .98	(6) .41	(24)	(15) .85	(3) .43	(3)	(8) .87	(3) .63	(6)	(15)1.09	(1) .40	(8)
6- 7	(40)1.00	(1) .90	(6)	(23) .88	.....	(2)	(12)1.11	(2) .35	(5)	(16)1.04	(1)1.00	(2)
7- 8	(25) .98	(1) .40	(6)	(31)1.14	.....	(6)	(13) .68	.....	(1)	(13)1.08	(3) .46	(2)
8- 9	(9) .88	(4) .40	(3)	(13) .82	(6) .48	(11)	(6) .76	(3) .66	(2)	(7) .86	(4) .72	(4)
9-10	(4) .45	.....	(1)	(4) .80	(11) .83	(8)	(3) .73	.....	(4)	(7) .76	(1) .50	(2)
10-11	(1) .40	(2)1.25	(3)	(5) .84	(5)1.14	(2)	(1) .40	(1) .30	(1)	.....	(4)1.12	(1)
11-12	(2)1.20	.....	(1)	(3) .50	(4) .75	(4)	.....	(1) .50	(2)	(2)1.15	.....	(1)

D - D

2- 3	(3) .73	(1)1.70	(2)	(6) .71	(1) .90	(1)	(1) .60	(2) .70	(2)	.....	.....	....
3- 4	(13) .52	(12) .52	(16)	(3) .40	(3) .70	(8)	(4) .55	(4) .34	(5)	(3) .50	(3) .43	(2)
4- 5	(14) .47	(19) .62	(26)	(6) .53	(7) .40	(5)	(3) .66	(5) .46	(7)	(4) .62	(2) .55	(8)
5- 6	(20) .47	(8) .40	(29)	(11) .67	(3) .86	(6)	(2) .65	(7) .40	(5)	(12) .53	(5) .34	(6)
6- 7	(25) .68	(1) .30	(18)	(12) .83	.....	(11)	(11) .73	(3) .50	(2)	(14) .67	.....	(5)
7- 8	(18) .61	(4) .42	(6)	(20) .74	(1) .30	(9)	(6) .56	(1) .40	(7)	(9) .60	(3) .40	(4)
8- 9	(7) .58	(1) .70	(5)	(12) .88	(5) .38	(11)	(3) .63	(1) .60	(3)	(5) .40	(1) .30	(5)
9-10	(1) .40	(2) .45	(3)	(12) .91	(4) .82	(5)	(2) .45	(1) .50	(3)	(3)1.03	.....	(4)
10-11	(4) .70	(1) .70	....	(7)1.17	(3) .73	(4)	(1)1.10	.....	(1)	(1)2.00	(1)1.00	(3)
11-12	(3) .46	(1)1.30	....	(4) .82	(2) .60	(1)	.....	(1) .60	(1)	(2) .40	.....	(1)

TABLE 2 *(Continued)*

E - E											
2- 3	(1) .80	.....	(1)	(2) .50	(1)1.30	....	.....	(1) .60	(1)	.....	.....	....
3- 4	(14) .54	(12) .65	(10)	(5) .38	(3) .56	(4)	(3) .70	(2) .65	(6)	(2) .55	(1) .30	(5)
4- 5	(18) .63	(17) .51	(24)	(7) .62	(3) .53	(7)	(3) .73	(2) .85	(10)	(8) .48	(1)1.40	(5)
5- 6	(29) .53	(6) .40	(24)	(9) .70	(3)1.00	(6)	(6) .50	(1) .50	(8)	(14) .55	(1) .60	(7)
6- 7	(26) .63	(5) .36	(15)	(7) .58	(2) .35	(12)	(10) .75	(1) .50	(7)	(14) .70	.....	(4)
7- 8	(17) .50	(3) .53	(8)	(16) .63	(5) .58	(14)	(9) .46	(3) .63	(4)	(9) .56	(3) .46	(6)
8- 9	(7) .54	.....	(10)	(14) .55	(4) .32	(16)	(7) .47	.....	(4)	(4) .45	(2) .40	(8)
9-10	(5) .88	(2) .30	(2)	(9) .82	(9) .51	(12)	(1) .40	(2) .45	(3)	(4) .67	(1) .40	(2)
10-11	(4) .55	(2) .55	(1)	(5) .56	(5) .80	(5)	(2) .50	.....	(1)	.....	(1) .50	(2)
11-12	(3) .33	.....	....	(5)1.06	(1)1.50	(1)	(1) .30	(1) .50	(..)	.....	(1) .60	(1)
Width												
2- 3	(2) .85	.....	....	(2)1.00	(1)1.40	....	(1) .30	.....	....	.....	.....	....
3- 4	(15) .66	(10) .62	(11)	(4) .82	(3) .70	(5)	(6) .63	(3) .66	(2)	(4) .67	(1) .30	(3)
4- 5	(23) .63	(16) .58	(20)	(8) .77	(3)1.00	(6)	(3) .83	(4) .62	(8)	(7) .67	(1)1.70	(6)
5- 6	(31) .67	(7) .55	(21)	(10) .71	(4) .82	(4)	(7) .55	(2) .80	(6)	(14) .73	(2) .55	(6)
6- 7	(25) .74	(7) .44	(14)	(10) .74	(2) .45	(9)	(13) .80	(1) .30	(4)	(13) .82	.....	(6)
7- 8	(18) .66	(1) .30	(9)	(18) .73	(7) .75	(10)	(9) .67	(2) .65	(5)	(9) .70	(5) .60	(4)
8- 9	(7) .65	(5) .32	(5)	(18) .66	(5) .50	(11)	(4) .72	(2) .35	(5)	(5) .50	(1) .70	(8)
9-10	(5) .96	(1) .50	(3)	(12) .75	(6) .60	(12)	(1) .70	(3) .60	(2)	(3) .90	(1) .30	(3)
10-11	(3) .53	(1) .90	(3)	(5) .70	(3) .83	(6)	(1) .40	(1) .50	(1)	.....	(2) .65	(1)
11-12	(2) .45	.....	(1)	(5) .82	(1)1.80	(1)	(1) .40	(1) .70	....	.....	(1)1.50	(1)
6 - 6												
6- 7	(4) .65	(1) .40	(1)	(1)2.50	(3) .83	(1)	(2) .75	.....	(1)	(2) .40	(3) .50	(1)
7- 8	(6) .66	(3) .56	(6)	(13) .62	(7) .70	(8)	.....	(2) .55	(4)	(11) .80	(2)1.00	(3)
8- 9	(7) .68	(1) .40	(5)	(15) .69	(5) .62	(18)	(5) .44	(1) .30	(3)	(4) .50	(1) .50	(10)
9-10	(4) .45	(3) .80	(3)	(15) .60	(7) .47	(13)	(3) .36	(2) .40	(3)	(5) .74	(3) .30	(3)
10-11	(3) .53	(2) .45	(3)	(3) .76	(10) .75	(12)	(2) .80	.....	(2)	(2) .55	(2) .45	(3)
11-12	(3) .60	.....	(1)	(3) .43	(4) .45	(5)	(1) .50	(1) .30	(1)	(2) .50	.....	(1)

FIG. 2. MANDIBLE: PERCENTAGE OF CASES MANIFESTING INCREMENT, DECREMENT, AND NEITHER, RESPECTIVELY, IN THE WIDTHS OF THE ALVEOLAR ARCH AT ANNUAL INTERVALS AND ACCORDING TO TYPE OF DENTAL OCCLUSION

TABLE 3a

Mean annual increment (+0.3 mm. or more), decrement (—0.3 mm. or less) and incidence of stability (0.0±0.2 mm.) in the lengths of the maxillary alveolar arch (both sexes)

AGE (*Yrs.*)	NORMAL +	NORMAL —	NORMAL 0	CLASS I(A) +	CLASS I(A) —	CLASS I(A) 0	CLASS II +	CLASS II —	CLASS II 0	CLASS I(B) +	CLASS I(B) —	CLASS I(B) 0
A - C												
2- 3	(1) .70	.....	(2)	(3) .76	(1) .40	(2)	.....	(3) .53	(2)	.....	.....	....
3- 4	(2) .35	(10) .39	(27)	(3) .40	(3) .56	(7)	(2) .45	(8) .41	(2)	.....	(7) .39	(1)
4- 5	(2) .45	(14) .45	(43)	(2) .55	(5) .64	(11)	(1) .90	(7) .50	(6)	(2) .65	(4) .35	(6)
5- 6	(7) .34	(8) .41	(40)	(4) .85	(6) .38	(6)	(2) .60	(5) .60	(5)	(4) .30	(3) .57	(10)
6- 7	(8) .52	(13) .57	(13)	(4) .55	(4) .70	(9)	(4) .75	(5) .68	(3)	(4) .50	(6) .83	(3)
7- 8	(9) .80	(3) .66	(8)	(18) .82	(4) .70	(9)	(7) .90	.....	(2)	(11) .95	.....	(1)
8- 9	(4) .67	(1) .30	(10)	(22) .70	(2) .35	(8)	(6) .90	.....	(4)	(9) .64	(4) .62	(2)
9-10	(4) .55	.....	(4)	(12) .55	(3) .73	(13)	(4) .50	.....	(2)	(4) .97	(1)1.10	(4)
10-11	(3) .50	.....	(1)	(5) .44	(1) .60	(9)	(1) .60	(1) .50	(1)	(2) .45	.....	(2)
11-12	(1) .30	(2) .50	(1)	(2) .60	(2) .45	(4)	.....	.....	(3)	(2) .60	.....	....
C - E												
2- 3	.....	(2) .70	....	.....	(2) .50	....	.....	(1) .30	(1)	.....	.....	....
3- 4	.....	(16) .50	(14)	(1) .40	(6) .46	(5)	(1) .60	(6) .53	(3)	(1) .70	(6) .55	(1)
4- 5	(1) .40	(31) .39	(28)	.....	(10) .46	(6)	.....	(7) .62	(8)	.....	(9) .44	(5)
5- 6	(2) .30	(23) .40	(35)	.....	(6) .46	(13)	.....	(8) .55	(8)	.....	(11) .44	(13)
6- 7	.....	(24) .39	(23)	(1) .30	(10) .58	(9)	.....	(8) .40	(11)	(1) .40	(8) .50	(8)
7- 8	(1) .70	(9) .52	(21)	(2) .40	(10) .55	(15)	.....	(3) .36	(12)	(3) .30	(8) .75	(7)
8- 9	(3) .30	(2) .40	(13)	(1) .30	(8) .50	(16)	.....	(3) .43	(8)	(1)1.40	(4) .52	(11)
9-10	(1) .60	(3) .36	(4)	(6) .50	(3) .46	(12)	(1) .40	(1) .30	(4)	(2) .90	(1) .40	(4)
10-11	(1) .30	.....	(3)	(1)1.00	(4) .42	(7)	.....	.....	(3)	.....	(1)1.30	(2)
11-12	(1) .50	(1) .50	(2)	(1) .30	(1) .40	(2)	(1) .40	.....	(3)	.....	(1) .70	....
Length												
2- 3	.....	(1) .40	....	.....	(1) .40	....	(1) .30	(1) .40	....	.....	.....	....
3- 4	(3) .43	(12) .58	(13)	(1) .50	(4) .60	(5)	(2) .60	(7) .91	(1)	(2) .60	(3) .93	(2)
4- 5	(4) .35	(27) .59	(27)	(3) .56	(10) .75	(3)	.....	(8) .83	(6)	(2)1.00	(5) .78	(5)
5- 6	(10) .54	(24) .52	(20)	(3)1.86	(6) .66	(8)	.....	(7) .65	(5)	(2) .40	(5) .60	(9)
6- 7	(10)1.00	(10) .62	(16)	(8)1.17	(4) .72	(5)	(6) .91	(3) .83	(3)	(4) .62	(5) .62	(3)
7- 8	(15) .94	(3) .93	(5)	(15)1.03	(3) .40	(7)	(9)1.16	(1) .70	(2)	(16) .79	(1) .30	(2)
8- 9	(5)1.02	(2) .50	(9)	(13) .68	(3) .76	(12)	(5)1.00	(1)1.40	(5)	(10) .60	(4) .47	(3)
9-10	(3) .56	(1) .40	(4)	(12) .69	(3) .46	(9)	(6) .38	.....	(2)	(4) .70	(3)1.13	(4)
10-11	(3) .60	.....	(3)	(8) .52	(11) .92	(1)	(2) .40	(1)1.20	....	(2) .55	(4)1.42	(1)
11-12	(1) .30	(2)1.00	(1)	.....	(4)1.25	(3)	.....	.....	(3)	.....	(1) .60	....

when increment and decrement, especially the latter, becomes respectively more common. The following year, 7-8, positive growth or increment is both prevailing and appreciable in amount, probably as a result of the forward movement of the erupted permanent incisors,[5] although even at this time the incidence of stability is quite high and, in fact, reverts as the most common phenomenon the year after (8-9 years).

Conditions in malocclusion, however, appear distinctly different. Class I (A), although exhibiting the same general trends as noted in normal occlusion, nevertheless also indicates definitely greater activity as manifested by the more frequent occurrence of decrement and increment (particularly the latter). The distinction is not so definite with regard to the rate of increment or decrement, although it is also somewhat greater than in normal occlusion.

The situation in Class II differs from that in either the normal or the Class I group. Decrement, to the extent of about half a millimeter, is by far the most common occurrence at 3-4, 4-5, and hardly less so, at 5-6 and 6-7 years. In sharp contrast, decrement apparently does not occur at all at 7-8 and 8-9 years, increment now completely prevailing and to a greater extent than in normal or Class I.

In short, the anterior length is evidently much more in a state of flux with respect to increment or decrement in malocclusion than in normal occlusion.

The behavior of the posterior length (C-E) is remarkably similar in normal and abnormal occlusion. On the other hand, it is distinctly dissimilar from the anterior length (A-C). Decrement and stability are now the prevailing phenomena, about equally common, up to 6-7 or 7-8 years; thereafter stability occurs almost exclusively. Increment is quite rare. Decrement, when occurring, is generally somewhat greater in amount in abnormal than in normal occlusion, although the differences do not appear to be substantial.

The total length, as might be expected, is characterized by a combination of the tendencies noted in the separate anterior and posterior segments. In normal occlusion decrement and stability are most common up to the 6-7 year period when the incidence of increment becomes equal to that of decrement; by 7-8 years increment is by far the most prevalent manifestation. The same general trend is noted in malocclusion, although in Class II between 3 and 6 years the occurrence of

[5] Measurements were taken of the permanent incisors only when these were substantially, at least one-half, erupted.

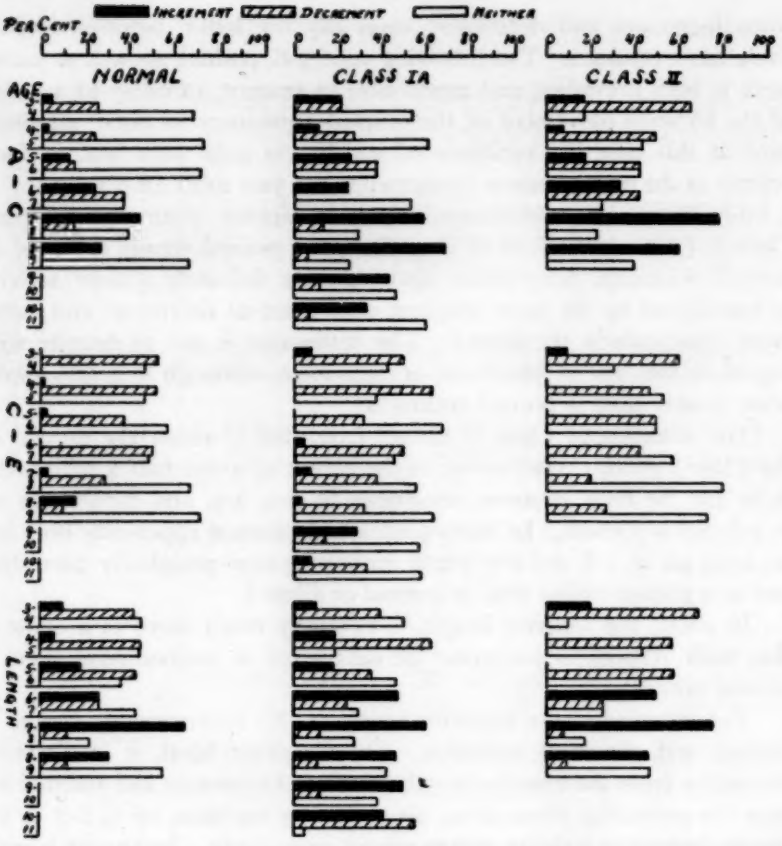

FIG. 3. MAXILLA: PERCENTAGE OF CASES MANIFESTING INCREMENT, DECREMENT, AND NEITHER, RESPECTIVELY, IN THE LENGTHS OF THE ALVEOLAR ARCH AT ANNUAL INTERVALS AND ACCORDING TO TYPE OF DENTAL OCCLUSION

decrement is much more common than in normal occlusion. Also the rate of decrement is generally greater in Class I (A) than in the normal group, and is even somewhat greater in Class II than in Class I (A).

Mandible. In the mandible, similar trends are noted in the A-C dimension as in the maxilla. The incidence of increment is high between 6 and 9 years regardless of type of occlusion. In Class I (A) where tolerably sufficient data are available for 9-10 and 10-11 years, increment appears also prevalent, especially in the latter age in contrast to the more stable conditions in the maxilla at this time. As in the maxilla,

TABLE 3b

TABLE 3b

Mean annual increment (+.3 mm. or more), decrement (—.3 mm. or less) and incidence of stability (0.0±0.2 mm.) in the lengths of the mandibular alveolar arch (both sexes)

AGE (Yrs.)	NORMAL +	NORMAL —	NORMAL 0	CLASS I(A) +	CLASS I(A) —	CLASS I(A) 0	CLASS II +	CLASS II —	CLASS II 0	CLASS I(B) +	CLASS I(B) —	CLASS I(B) 0
A - C												
2- 3	(1) .70	.....	(4)	(2) .80	(1) .50	(4)	(1) .40	(2) .45	(2)	.....	.....	....
3- 4	(5) .54	(6) .46	(30)	(4) .30	(3) .43	(7)	(3) .66	(3) .42	(7)	(1) .40	(3) .56	(4)
4- 5	(4) .32	(10) .43	(44)	(5) .48	(4) .57	(8)	.....	(11) .56	(4)	(1) .30	(3) .43	(8)
5- 6	(3) .43	(21) .94	(28)	(2) .60	(8) .90	(6)	(3) .86	(6) .68	(5)	(2) .60	(9) .57	(6)
6- 7	(12) .65	(14) .76	(7)	(12) .67	(7)1.05	(4)	(7) .67	(5) .76	(4)	(5) .48	(6) .68	(4)
7- 8	(11) .64	(5) .80	(12)	(15) .86	(12) .59	(8)	(9) .77	(4) .57	(2)	(6) .68	(6) .65	(3)
8- 9	(5) .48	(4) .90	(6)	(8) .55	(4) .50	(18)	(4) .42	(3) .36	(4)	(5) .34	(4) .40	(6)
9-10	(1) .40	.....	(4)	(7) .60	(4) .75	(13)	(1) .90	(1) .30	(5)	(1) .30	(4) .32	(5)
10-11	(1) .70	(1) .50	(4)	(8) .57	(1) .60	(3)	(2) .65	.....	(1)	(3) .36	(1) .70	(2)
11-12	.....	(1) .40	(2)	(3)1.03	(3) .50	(5)	.....	(2) .50	(1)	(1) .50	(1) .70	(1)
C - E												
2- 3	.....	(2) .50	....	.....	(2) .40	(1)	.....	(2) .75	....	.....	.....	....
3- 4	(2) .35	(14) .49	(20)	(1) .30	(5) .40	(6)	(1) .30	(6) .38	(4)	.....	(5) .38	(2)
4- 5	.....	(25) .40	(34)	(1) .30	(8) .41	(8)	(1) .30	(3) .53	(11)	(2) .40	(6) .48	(6)
5- 6	.....	(26) .45	(33)	.....	(6) .58	(12)	.....	(6) .43	(9)	.....	(11) .50	(12)
6- 7	.....	(18) .44	(26)	(2) .50	(6) .60	(13)	(2) .40	(4) .72	(12)	.....	(6) .46	(12)
7- 8	(4) .37	(9) .56	(14)	(2) .30	(8)1.13	(22)	(2) .30	(5) .36	(7)	(3) .53	(6) .48	(7)
8- 9	(2) .75	(5) .34	(7)	(3) .30	(6) .50	(19)	(4) .35	(1) .30	(5)	(1) .40	(5) .48	(7)
9-10	.....	(1) .50	(4)	(3) .90	(5) .50	(15)	.....	(1)1.00	(4)	.....	(2) .65	(4)
10-11	(1) .40	(3) .80	(2)	(2)1.00	(5)1.34	(1)	.....	(1) .90	(2)	.....	(2)1.00	....
11-12	(1) .80	.....	(2)	(1) .70	(3) .56	(2)	(1) .90	.....	(1)	.....	.....	(2)
Length												
2- 3	.....	.....	(1)	.....	(1) .40	(2)	.....	(1) .90	....	.....	.....	....
3- 4	(2) .30	(16) .56	(17)	(4) .57	(3) .76	(5)	(1) .30	(5) .40	(4)	.....	(6) .55	(2)
4- 5	(5) .40	(25) .56	(26)	(3) .56	(5) .48	(8)	(1) .40	(9) .64	(5)	(2) .65	(6) .66	(5)
5- 6	(8) .37	(22) .64	(23)	(2) .95	(7)1.02	(8)	(2) .55	(3) .66	(8)	(2) .45	(9) .49	(8)
6- 7	(15) .70	(10) .70	(13)	(12) .87	(3) .76	(4)	(5) .74	(4) .47	(8)	(6) .80	(4) .60	(7)
7- 8	(8) .53	(8) .60	(11)	(13) .69	(10) .63	(11)	(6) .76	(2) .65	(8)	(3) .33	(5) .66	(8)
8- 9	(6) .55	(4) .47	(7)	(10) .49	(9) .48	(15)	(4) .85	(2) .50	(5)	(5) .48	(5) .40	(4)
9-10	(3) .70	(3) .50	(3)	(8) .55	(9) .65	(13)	.....	(2) .50	(4)	(1) .60	(5) .82	(2)
10-11	(2) .30	(3) .83	(2)	(5) .52	(5)1.50	(4)	.....	(1) .30	(2)	.....	(2)1.35	(2)
11-12	(1) .50	(1) .40	(1)	(1)1.00	(4)1.15	(2)	.....	(1) .70	(1)	.....	.....	(2)

stability is more common in normal than in malocclusion between 3 and 6 years, Class I (A) manifesting a higher incidence of increment and Class II a relatively greater number with decrement, each in comparison with conditions in normal occlusion. With respect to rate of increment, or decrement, the amounts are particularly high between 5 and 8 or 9 years. The differences relative to occlusion are not consistent.

The posterior length (C-E) in normal occlusion is distinguished by decrement and stability in a more or less equal proportion of the subjects. Class I (A) malocclusion manifests an essentially similar picture

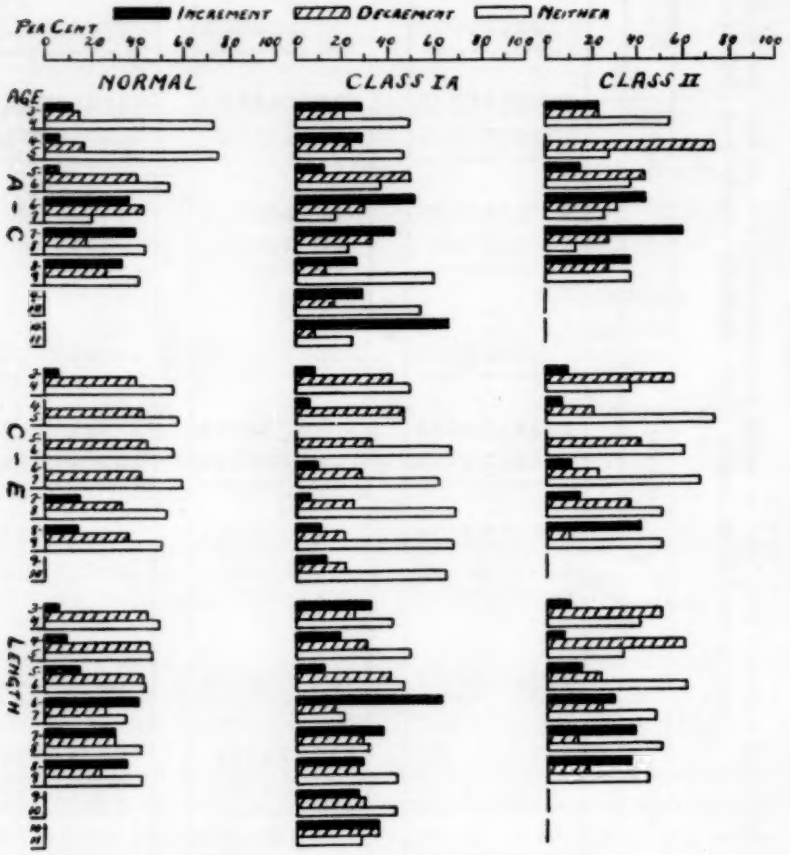

FIG. 4. MANDIBLE: PERCENTAGE OF CASES MANIFESTING INCREMENT, DECREMENT, AND NEITHER, RESPECTIVELY, IN THE LENGTHS OF THE ALVEOLAR ARCH AT ANNUAL INTERVALS AND ACCORDING TO TYPE OF DENTAL OCCLUSION

with stability perhaps generally more common. Also, decrement, when occurring in the latter, is not infrequently greater in amount than in the normal group. A surprisingly high proportion of cases in Class II exhibits increment between 8-9 years, but the amount is slight and the number of cases in this age interval is in fact quite small.

Regarding total length, here, too, decrement and stability predominate in normal occlusion between 3 and 6 years, the incidence of increment however, rising sharply thereafter. In contrast, increment is generally more common in Class I (A) while decrement, in the early years, occurs more frequently in Class II.

Frequency of various rates of increment and decrement

In addition to the average increment or decrement, it is manifestly also important to know the divergence from the central tendency, both in number and in extent. This question is treated in Tables 4a, 4b and 4c. The total length, anterior width (C-C) and posterior width (Width) are considered in this connection. Moreover, in order to attain larger series, the several ages were combined into three main periods, namely, 2-5 years, 5-8 years, and 8-11 years. These age periods suggested themselves as natural groupings from the preceding, according to which the first period appears as one of general quiescence; the second, one of marked activity; and the third, one of rather mixed tendencies. The 11-12 year interval was not included because the permanent canines and premolars were displacing the deciduous predecessors at about this time, complicating matters; besides, the number of cases at this age was extremely small.

Now, it is of the utmost importance to remember that the indicated increment or decrement is not that between 2 and 5 years, or 5 and 8 years, but refers to a one-year interval within these age limits; increment between 5 and 8 years, for example, signifies the rate of increase either between 5-6 years, 6-7 years, or 7-8 years; and similarly for the other age periods. The increment or decrement covers a period of one year only in any case.

The data are presented according to sex when the available series appeared to justify the subdivision.

Turning to the tabular matter (Tables 4a, 4b and 4c), we find that not infrequently the amount of increment, or even decrement, during an interval of only one year, is surprisingly large, indeed, more than had previously been averaged for as much as 7 or 8 years (Goldstein

TABLE 4a

Frequency distribution of number of cases with the indicated rates of increment or decrement in the anterior width (C-C) of the alveolar arches at annual intervals between the given age limits

CHANGE (*mm.*)	NORMAL				CLASS I(A)				CLASS II			CLASS I(B)		
	2-5	5-8		8-11	2-5	5-8		8-11	2-5	5-8	8-11	2-5	5-8	8-11
	MF	M	F	MF	MF	M	F	MF	MF	MF	MF	MF	MF	MF
Maxilla														
Increment														
.3- .5	22	12	19	3	10	8	8	12	3	6	6	5	11	12
.6- .8	7	9	9	7	4	10	2	11	1	6	.	1	4	1
.9-1.1	3	6	5	.	2	3	2	5	2	10	1	1	14	3
1.2-1.4	.	5	13	.	1	5	3	1	.	8	.	1	8	3
1.5-1.7	.	6	8	2	.	3	7	2	.	2	.	.	2	2
1.8-2.0	.	2	3	1	.	6	4	2	.	3	.	.	3	.
2.1-2.3	.	1	5	.	.	5	2	2	.	1	.	.	2	1
2.4-2.6	.	1	.	.	.	1	.	.	.	.	.	.	.	.
2.7-2.9	.	.	.	.	.	1	.	.	.	1	.	.	.	.
Decrement														
.3- .5	20	5	3	5	1	1	.	10	8	4	2	4	1	.
.6- .8	7	2	.	.	1	1	1	2	4	2	1	1	1	1
.9-1.1	.	.	.	1	1	.	1	1	.	.	.	.	.	3
1.2-1.4	1	.	.	.	2	1	.	1	.	.	.	.	.	.
1.5-1.7	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Mandible														
Increment														
.3- .5	17	10	9	7	10	9	7	8	2	7	5	3	9	4
.6- .8	7	11	15	2	3	10	9	6	2	9	3	3	5	6
.9-1.1	2	9	11	2	1	8	3	3	1	10	1	4	15	1
1.2-1.4	1	4	10	3	1	6	4	2	.	4	.	.	6	2
1.5-1.7	.	4	6	.	.	5	3	2	1	1	.	.	5	.
1.8-2.0	.	2	2	.	1	1	2	1	.	2	1	.	1	1
2.1-2.3	.	1	1	.	.	.	.	.	.	.	.	.	2	.
2.4-2.6	.	.	1	.	.	.	.	.	.	.	.	.	.	.
2.7-2.9	.	.	.	.	.	2	.	.	.	.	.	.	.	.
3.0-3.2	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Decrement														
.3- .5	21	3	3	4	7	2	.	9	6	3	2	3	3	3
.6- .8	4	1	.	1	2	1	.	8	2	2	1	.	1	3
.9-1.1	.	.	1	.	.	.	.	1	.	.	1	1	1	.
1.2-1.4	.	.	.	.	.	.	.	.	1	.	.	.	.	2
1.5-1.7	.	.	.	.	.	.	.	1	.	.	.	.	.	.
1.8-2.0	.	.	.	.	.	.	.	1	.	.	.	.	.	1
2.1-2.3	.	.	.	1	.	.	.	2	1	.	.	.	.	.

Note: M is male; F is female; MF is male combined with female.

TABLE 4 b

Frequency distribution of number of cases with the indicated rates of increment or decrement in the posterior width (width) of the alveolar arches at annual intervals between the given age limits

CHANGE (*mm.*)	NORMAL				CLASS I(A)				CLASS II			CLASS I(B)		
	2-5	5-8		8-11	2-5	5-8		8-11	2-5	5-8	8-11	2-5	5-8	8-11
	MF	M	F	MF	MF	M	F	MF	MF	MF	MF	MF	MF	MF
Maxilla														
Increment														
.3- .5	18	12	15	6	3	6	9	13	9	9	6	2	11	3
.6-. 8	15	13	10	2	1	6	3	6	3	8	2	4	12	3
.9-1.1	7	12	13	4	5	7	3	7	.	7	2	3	9	3
1.2-1.4	7	2	5	2	2	3	1	4	.	2	.	1	2	1
1.5-1.7	3	.	.	1	2	1	.	3	.	.	1	1	3	1
1.8-2.0	2	.	.	.	.	.	1	.	.	1	.	1	.	1
2.1-2.3	.	.	1	.	.	.	.	1	.	.	.	1	.	.
2.4-2.6	.	.	.	.	.	.	.	1	.	.	.	.	.	.
2.7-2.9	.	.	.	.	.	.	.	.	.	.	.	.	.	2
3.3-3.5	.	.	.	.	.	1	.	.	.	1	.	.	.	.
Decrement														
.3- .5	9	6	6	4	3	5	2	10	3	1	5	1	7	1
.6- .8	6	4	2	1	1	1	1	3	.	1	1	1	.	2
.9-1.1	1	.	.	2	.	.	1	1	2	2	.	.	1	1
1.8-2.0	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Mandible														
Increment														
.3- .5	21	15	13	6	3	9	5	14	7	14	3	7	11	4
.6- .8	11	10	16	5	4	9	3	14	1	3	2	1	11	2
.9-1.1	3	2	11	2	6	3	3	4	1	6	.	.	10	1
1.2-1.4	4	3	3	1	1	2	2	2	.	6	1	2	3	.
1.5-1.7	.	.	1	.	.	1	1	.	1	.	.	1	1	.
1.8-2.0	1	.	.	.	.	.	.	.	.	.	.	.	.	1
2.1-2.3	.	.	.	.	.	.	.	1	.	.	.	.	.	.
2.4-2.6	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Decrement														
.3- .5	12	10	1	6	1	5	1	7	3	2	5	1	4	2
.6- .8	8	.	2	.	2	1	3	5	2	1	.	.	2	1
.9-1.1	6	.	2	1	2	.	1	1	2	2	1	.	1	1
1.2-1.4	.	.	.	.	2	.	.	1	.	.	.	.	.	.
1.5-1.7	.	.	.	.	.	1	.	.	.	.	.	1	.	.
1.8-2.0	.	.	.	.	.	1	.	.	.	.	.	.	.	.

Note: M is male; F is female; MF is male combined with female.

TABLE 4c

Frequency distribution of number of cases with the indicated rates of increment or decrement in the total length (length) of the alveolar arches at annual intervals between the given age limits

CHANGE (mm.)	NORMAL				CLASS I(A)				CLASS II			CLASS I(B)		
	2-5	5-8		8-11	2-5	5-8		8-11	2-5	5-8	8-11	2-5	5-8	8-11
	MF	M	F	MF	MF	M	F	MF	MF	MF	MF	MF	MF	MF
Maxilla														
Increment														
.3- .5	6	7	5	2	2	5	2	17	2	4	8	1	10	9
.6- .8	1	5	4	7	2	3	1	9	1	2	2	1	6	4
.9-1.1	.	3	3	1	.	1	1	4	.	1	1	1	4	2
1.2-1.4	.	2	2	.	.	1	.	1	.	3	1	.	.	.
1.5-1.7	.	1	.	.	.	4	2	1	.	3	1	.	1	.
1.8-2.0	.	1	1	1	.	3	1	1	.	2	.	.	.	.
2.1-2.3	.	.	1	.	.	.	1	.	.	.	.	.	1	1
2.4-2.6	.	.	.	.	.	1	.	.	.	.	.	1	.	.
Decrement														
.3- .5	22	13	8	3	8	2	3	7	4	3	.	2	6	3
.6- .8	13	7	3	.	3	6	1	4	4	6	.	2	4	4
.9-1.1	3	.	3	.	3	.	1	3	4	1	.	3	1	.
1.2-1.4	1	1	.	.	.	.	.	1	3	1	2	1	.	2
1.5-1.7	1	2	.	.	1	.	.	1	1	.	.	.	.	.
2.1-2.3	.	.	.	.	.	.	.	.	.	.	.	.	.	2
2.4-2.6	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Mandible														
Increment														
.3- .5	7	6	10	5	4	9	3	14	2	3	2	1	6	4
.6- .8	.	5	5	6	2	2	4	7	.	7	1	.	4	2
.9-1.1	.	1	3	.	1	1	.	2	.	2	.	1	.	.
1.2-1.4	.	.	1	.	.	2	3	.	.	1	.	.	.	.
1.5-1.7	.	.	.	.	.	3	.	.	.	.	1	.	.	.
1.8-2.0	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Decrement														
.3- .5	24	7	10	6	6	8	1	12	7	5	3	9	11	6
.6- .8	10	6	8	3	1	1	5	5	6	1	2	1	6	3
.9-1.1	7	4	3	.	2	1	.	1	1	3	.	1	.	.
1.2-1.4	.	1	1	.	.	2	.	1	1	.	.	1	1	1
1.5-1.7	.	.	.	1	.	1	.	2	.	.	.	.	.	2
1.8-2.0	.	.	.	.	.	.	.	1	.	.	.	.	.	.
2.1-2.3	.	.	.	.	.	1	.	1	.	.	.	.	.	.

Note: M is male; F is female; MF is male combined with female.

and Stanton, '35; Brash, '24). This is readily comprehended in view of the fact that the general average must have been based on cases which remained stable or actually diminished in size from one year to the next (these latter facts not being ascertainable from a strictly cross-sectional study).

The high average increment already noted between 5 and 8 years is corroborated by the frequency distribution which discloses a correspondingly high proportion of cases with an accelerated rate of growth at this time.

The number of cases with appreciable decrement in normal occlusion, and between 2 and 5 years of age, is remarkable. Abnormal occlusion, as might be expected, is generally more variable in the range both of increment and decrement.

ABSOLUTE DIMENSIONS

The question arose, after studying the annual rate of change in the alveolar arches with respect to type of occlusion, whether the absolute dimensions varied in the normal and deformed arches, and if so, to what extent? In other words, was the deciduous arch in normal occlusion wider or narrower, longer or shorter, than in abnormal occlusion?

It may be recalled that Franke ('22) contributed data on this question, and Brash ('24) has further interpreted this same material. Unfortunately, these studies, based on skeletal remains, are not quite comparable with the present data, particularly with reference to age groupings; e.g. in the former, 2-7 years comprises one group, and 8-13 years the following.

The data to follow refer to the alveolar arches of males only. A combination of both sexes did not seem permissable inasmuch as the arch of the female is generally smaller than that of the male, and a discrepancy in the number of cases between the sexes would consequently directly affect the average dimensions; i.e. the more males, the higher the average; the more females, the less the average.

This simple fact, we must confess, was overlooked by ourselves in one of our previous reports ('35) in which the absolute dimensions of both sexes were combined. Luckily, the conclusions in the report happen not to be affected in any essential respect as confirmed, in this same paper, by a further analysis of the data with regard to sex.

In the present instance, our intention at first was to consider the 5-year age period only (4 years, 6 months to and including 5 years, 5 months), which represented the maturity, as it were, of the deciduous dentition; what is more, a fairly adequate number of cases was available at this particular age. However, in view of the marked activity in the development of the arches noted between 5 and 8 years, the data for the latter age were also calculated albeit the occlusion categories at this time were not as well represented in numbers as could be desired. It will be recalled that the permanent central incisors are pretty well erupted by 8 years, as are also the permanent first molars.

One further comment before proceeding with the analysis of the tabular material. The absolute dimensions representing the posterior width and length, E-E and C-E respectively, are not considered in the present instance, both in order to conserve space and because no essential consideration would seem to be lost by their omission, inasmuch as the total width is also a posterior measurement and the total length, considered in conjunction with A-C, indicates substantially the behavior of the length between the canines and deciduous second molars. Also, width and length were selected because their measurement calls for no specially refined technique, thereby perhaps stimulating similar observations by others for the purpose of checking and comparison with the data presented herein.

Turning to the results culled from Table 5, we note the following. At 5 years of age the anterior width (C-C) in normal occlusion (maxilla and mandible) is greater than the corresponding diameter in malocclusion. The difference is about the same in Class I (A) and Class II, namely 0.6 and 0.7 mm. less, respectively, in the maxilla; and 0.5 and 0.3 mm. less, respectively, in the mandible, each as compared with conditions in normal occlusion. A much greater discrepancy (1.3 mm.) is suggested in Class I (B), maxilla.

Between 5 and 8 years of age, striking changes seem to have occurred. The diameter C-C has increased appreciably regardless of occlusion, but even more rapidly in the abnormal groups than in normal occlusion so that now the anterior width, both in maxilla and mandible, is practically identical in normal and abnormal occlusion. A possible exception is the Class I (B) in which the dimension in the maxilla is still a millimeter less than normal while in the mandible it has actually become slightly larger than in the normal.

TABLE 5

Comparison of mean dimensions (mm.) and form (W/L index) of alveolar arch in normal and abnormal occlusion (males)

		Norm.	Class I(A)	Diff.	Class II	Diff.	Class I(B)	Diff.
			MAXILLA					
C - C	5 Yrs.	(42) 27.9	(19) 27.3	+0.6	(15) 27.2	+0.7	(14) 26.6	+1.3
	8 Yrs.	(19) 30.1	(25) 30.1	0.0	(9) 29.8	+0.3	(10) 29.1	+1.0
		+2.2	+2.8		+2.6		+2.5	
Width	5 Yrs.	(42) 48.1	(17) 46.9	+1.2	(15) 47.3	+0.8	(14) 46.4	+1.7
	8 Yrs.	(19) 49.3	(21) 48.8	+0.5	(9) 48.2	+1.1	(9) 48.1	+1.2
		+1.2	+1.9		+0.9		+1.7	
A - C	5 Yrs.	(42) 6.9	(19) 7.3	—0.4	(14) 6.9	0.0	(14) 6.6	+0.3
	8 Yrs.	(15) 7.3	(24) 7.2	+0.1	(7) 7.6	—0.3	(9) 6.6	+0.7
		+0.4	—0.1		+0.7		0.0	
Length	5 Yrs.	(41) 28.9	(17) 29.6	—0.7	(14) 29.5	—0.6	(13) 28.4	+0.5
	8 Yrs.	(17) 29.0	(20) 29.1	—0.1	(7) 30.0	—1.0	(10) 27.8	+1.2
		+0.1	—0.5		+0.5		—0.6	
W/L	5 Yrs.	(41)166.6	(17)158.7		(14)160.1		(13)164.8	
index	8 Yrs.	(17)170.3	(20)167.5		(7)160.4		(7)160.4	
Palate	5 Yrs.	(42) 11.8	(18) 12.0	—0.2	(15) 11.7	+0.1	(14) 11.4	+0.4
height	8 Yrs.	(19) 12.5	(27) 12.6	—0.1	(9) 12.5	0.0	(10) 12.8	—0.3
		+0.7	+0.6		+0.8		+1.4	
			MANDIBLE					
C - C	5 Yrs.	(42) 22.1	(19) 21.6	+0.5	(15) 21.8	+0.3	(14) 22.0	+0.1
	8 Yrs.	(19) 24.0	(28) 23.9	+0.1	(8) 23.9	+0.1	(9) 24.3	—0.3
		+1.9	+2.3		+2.1		+2.3	
Width	5 Yrs.	(41) 44.9	(18) 44.1	+0.8	(15) 44.7	+0.2	(13) 44.5	+0.4
	8 Yrs.	(17) 46.0	(25) 45.5	+0.5	(9) 45.3	+0.7	(8) 45.8	+0.2
		+1.1	+1.4		+0.6		+1.3	
A - C	5 Yrs.	(41) 4.3	(18) 4.2	+0.1	(15) 4.2	+0.1	(11) 4.5	—0.2
	8 Yrs.	(19) 3.9	(26) 3.9	0.0	(8) 4.5	—0.6	(8) 4.2	—0.3
		—0.4	—0.3		+0.3		—0.3	
Length	5 Yrs.	(40) 26.2	(17) 25.7	+0.5	(15) 26.1	+0.1	(11) 26.5	—0.3
	8 Yrs.	(17) 25.7	(24) 25.2	+0.5	(9) 25.9	—0.2	(8) 24.9	+0.8
		—0.5	—0.5		—0.2		—1.6	
W/L	5 Yrs.	(40)171.4	(17)171.4		(15)171.4		(11)167.4	
index	8 Yrs.	(17)179.0	(24)181.1		(9)174.9		(9)174.9	

Note: Class I (A), excessive overbite only. Class I (B), all other Class I.

The posterior width (Width) manifests both similar and dissimilar trends. At 5 years the dimension in normal occlusion is definitely greater than in malocclusion (maxilla and mandible), especially in contrast to the Class I type of malocclusion. By 8 years of age, however, the discrepancy between the dimensions in normal and Class I (A) cases is much diminished, although the former still manifests a broader arch. On the other hand, Class II now is distinguished by a relatively narrower arch than at 5 years, as compared with the normal. In other words, growth occurs more rapidly in normal occlusion as compared with Class II malocclusion, but somewhat less rapidly than apparently occurs in Class I malocclusion.

Examining the lengths of the arch, we find some rather surprising results.

At 5 years the anterior length of the maxilla (A-C) is greater in Class I (A) than in normal, although not as much as might be expected (0.4 mm.) in view of the excessive horizontal overbite;[6] in Class II, however, where an even longer length than in Class I (A) was anticipated, it is actually the same as in normal occlusion. Moreover, the diameter appears virtually the same in the mandible regardless of type of occlusion.

By 8 years of age, the A-C length of the maxilla has apparently increased in the normal group while remaining practically stable in Class I (A), so that the character is becoming alike in each; in Class II, however, it has also increased and more so than the normal, consequently manifesting at this time a greater anterior length than the latter. This is also true of the mandible in Class II, while in normal and Class I (A) occlusion the A-C has actually diminished. Considering total length, at 5 years we note that it is appreciably longer in the maxilla in abnormal than in normal occlusion. Interestingly enough, at 8 years the length is seen to have remained the same in normal occlusion while having diminished 0.5 mm. in Class I (A) and increased 0.5 mm. in Class II. The diameter has therefore become alike in normal and Class I (A) occlusion at 8 years of age, but much longer in Class II as compared with the normal.

In the mandible at 5 years, the length appears shorter by 0.5 mm. in Class I (A) but scarcely so (0.1 mm.) in Class II, also as compared

[6] In this connection it must be remembered that excessive overbite refers to the distance between the incisors, the incisal edges really, while in the present instance it is the alveolar arch that is under consideration.

with normal occlusion. The dimension has apparently diminished between 5 and 8 years, to the same extent in normal and Class I (A)—0.5 mm.—but only 0.2 mm. in Class II.

Palate height is also given, relative to type of occlusion. This measurement was made from the lowest lingual gum margin at the second deciduous molar (left side), in a vertical line to the deepest part of the palate, the model being held in the occlusal plane.

Much to our surprise, the depth appears to be virtually alike in normal and abnormal occlusion, both at 5 and 8 years, respectively. It apparently increases during this period a little more than half a millimeter (except in Class I (B) where it is somewhat greater). It is of some interest to note that, according to Smyth and Young ('32), the palate height in boys with normal occlusion increases, between 5 (4 plus 5 years) and 8 years, 0.52 mm., a very similar amount to that found in the present material.

FORM OF ALVEOLAR ARCH

The form of the arch as represented by the width/length index, and considered with regard to type of occlusion, should be of considerable interest. Our previous paper on the development of the arches ('35) illustrated the actual correspondence of form with the several indices demarcating respectively the limits of the dolichouranic, mesuranic, and brachyuranic classes.

Tables 6a and 6b present the results with reference to occlusion. Examining the maxilla first, we find that the prevailing arch form at 5 years is divided between the mesuranic and dolichouranic limits. The latter form, however, is somewhat more common in Class I (A) than either in normal or Class II occlusion; more striking, however, is the total lack of the relatively broad arch at this time except in Class I (A).

By 8 years the dolichouranic form is distinctly less prevalent while a relatively marked rise of the brachyuranic type occurs both in the normal and Class I (A) groups, respectively, but still is completely absent in Class II.

By 8 years the dolichouranic form is distinctly less prevalent while a relatively marked rise of the brachyuranic type occurs both in the normal and Class I (A) groups, respectively, but still is completely absent in Class II.

TABLE 6a

Form of the maxillary alveolar arch (width/length index) in normal and abnormal occlusion

OCCLUSION	MALES, 5 YEARS OLD						MALES, 8 YEARS OLD					
	Dolicho-uranic x-158.9		Mes-uranic 159.0-184.1		Brachy-uranic 184.2-x		Dolicho-uranic x-158.9		Mes-uranic 159.0-184.1		Brachy-uranic 184.2-x	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	(17)	41.5	(24)	58.5	...	...	(3)	33.3	(4)	44.4	(2)	22.2
Class I(A)	(8)	47.0	(7)	41.1	(2)	11.8	(12)	36.4	(14)	42.4	(7)	21.2
Class II	(5)	33.3	(10)	66.7	...	...	(2)	25.0	(6)	75.0	...	...

The average indices are of interest, too (Table 5). At 5 years the form is mesuranic in normal occlusion but dolichouranic in Class I (A) and on the borderline of the dolichouranic form in Class II. In the 8th year, however, the arch is definitely mesuranic both in the normal and Class I (A) categories, but remains practically unchanged in Class II.

The form of the mandibular arch is considered in Table 6b. Here, more than in the maxilla, apparently, is suggested a definite correlation between dental occlusion and form of arch. Individuals with mal-

TABLE 6b

Form of the mandibular alveolar arch (width/length index) in normal and abnormal occlusion

OCCLUSION	MALES, 5 YEARS OLD						MALES, 8 YEARS OLD					
	Dolicho-uranic x-168.9		Mes-uranic 169.0-188.9		Brachy-uranic 189.0-x		Dolicho-uranic x-168.9		Mes-uranic 169.0-188.9		Brachy-uranic 189.0-x	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	(7)	17.1	(34)	82.9	...	...	(1)	5.9	(15)	88.2	(1)	5.9
Class I(A)	(12)	70.5	(5)	29.4	...	...	(4)	20.0	(15)	75.0	(1)	5.0
Class II	(8)	57.1	(6)	42.9	...	...	(3)	42.8	(4)	57.1	...	..

occlusion manifest most commonly a dolichouranic arch, especially in Class I (A), in contrast to the prevailing mesuranic form noted in subjects with normal occlusion. The brachyuranic form does not occur in our material at this age, and it would probably be infrequent even in a larger series.

Between 5 and 8 years, the dolichouranic form has become generally less common, much so in normal occlusion. Although markedly diminished in relative frequency in Class I (A), it is still several times more frequent than in normal occlusion; and, in Class II, it is likewise still prevalent, being in fact more than twice as common as in Class I (A). Of interest, too, is the appearance albeit infrequently of a relatively broad arch in the normal and Class I (A) groups.

It must be remembered that, regrettably enough, the number of total cases in several of the categories is small, and the results must perforce be considered tentative only.

Regarding the average indices (Table 5), we note that at 5 years of age they are identical in normal and abnormal occlusion. In any event, it would appear that at this time the arch form is barely mesuranic. By 8 years, however, the average form is generally and definitely (less so in Class II) mesuranic.

SUMMARY

The problem was to investigate the development of the alveolar arches with respect to type of dental occlusion, in the same (285) children at annual intervals between 2 and 12 years of age. The main results were:

(1) The widths of the alveolar arches during the period of one year manifest not only increment but also, and particularly between 3 and 5 years, decrement or stability in a considerable proportion of the cases.

(2) Annual increment is by far the most common occurrence in the widths of the arches between 5 and 8 years, especially in the 7-8 year interval, both in normal and abnormal occlusion respectively. The rate of increment is also highest (about 1.0 mm. average) during this time.

(3) Compared with conditions in normal occlusion, the widths of the arches in Class I (A) appear more susceptible to increment and in somewhat greater amount (especially between 3-5 years) whereas the

incidence of decrement tends to be higher (in frequency of occurence) in Class II malocclusion.

(4) Annual increment appears more general and to a somewhat greater extent in the anterior or canine width of the arches (especially in Class I malocclusion) than in the posterior or bi-molar region.

(5) The anterior length (A-C) of the arches is in a greater state of flux, stability being less common, in abnormal than in normal occlusion.

(6) The posterior length (C-E) is characterized by decrement and stability in about equal frequency up to 7 or 8 years of age, after which stability prevails. Increment is rare.

(7) Decrement and stability are also prevalent in the total length of the arches up to 6 or 7 years, after which and particularly between 7-8 years increment is the most common phenomenon.

(8) In many cases the amount of annual increment or decrement is considerable, the former being as much as and more than had often been averaged for a number of years.

(9) At 5 years of age the arches are narrower in abnormal than in normal occlusion; by 8 years of age the anterior width is the same in normal and abnormal occlusion while the posterior width in Class I (A) closely approaches the diameter in normal occlusion and the dimension in Class II remains narrower than the normal.

(10) The anterior length at 5 years is the same in normal and abnormal (Class IA and Class II) occlusion except in the maxilla of Class I (A) where it is longer than the normal. By 8 years the diameter in Class I (A) is like that in normal occlusion (both jaws) but has become longer than the normal in Class II malocclusion.

(11) Compared with conditions in normal occlusion, the total length of the maxilla at 5 years is greater in abnormal occlusion; that of the mandible is less in Class I (A) and similar in Class II malocclusion, respectively. By 8 years the length of the maxilla in Class I (A) has become similar to the normal dimension but in the mandible still remains shorter. In Class II, conditions remain unchanged, namely, greater length of the maxilla but a like dimension in the mandible, each as compared with the normal.

(12) At 5 years of age the form of the maxillary arch is about equally divided between the dolichouranic and mesuranic types (both in normal and abnormal occlusion), the brachyuranic or relatively broad

arch being rare. By 8 years the dolichouranic form is much less common, the mesuranic being most prevalent with a relatively considerable increase in the brachyuranic form in normal and Class I (A) occlusion.

(13) At 5 years of age the form of the mandibular arch is dolichouranic in form much more frequently in abnormal than in normal occlusion. The brachyuranic type is rare. At 8 years the dolichouranic form is also generally less frequent, but is still more common in Class I (A) malocclusion than in normal occlusion, and is even relatively more characteristic of Class II than of Class I.

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CONTOUR MAPS, CENTER OF GRAVITY, MOMENT OF INERTIA AND SURFACE AREA OF THE HUMAN BODY*

BY A. P. WEINBACH

The Normal Child Development Study of the Department of Diseases of Children, Columbia University and the Babies Hospital, New York

INTRODUCTION

THE construction of volume contour maps of the human body offers a means of following the relative growth of the parts of the individual. The center of gravity of the body or its parts and the moment of inertia of the body or its parts may be determined approximately from these maps. Surface area of the body or its parts may be approximated by preparing a surface contour map. If the volume contour maps are plotted in per cent of the height, the maps may be superimposed for the comparison of the relative growths of the extremities, the hips, the head, etc. This technique of following body volume contours is particularly adaptable to longitudinal studies of one individual.

VOLUME CONTOUR MAPS

The volume contour maps are obtained by means of direct measurement or by the use of two photographs, one a front view, the other a side view. These two photographs may be taken separately or on one negative by placing a mirror at an angle of 45° to the individual. The photographs should be taken at about twenty feet from the individual to minimize distortion and to give a flat picture. The negatives may then be enlarged to any desired workable size. The front and side views may be enlarged to exactly the same size (i.e. height) to minimize computations.

* The author is indebted to Kenneth Breeze for the necessary photography and for carefully drawing the charts for this paper; and to C. W. P. Walter for assistance in the preparation of the manuscript.

With the basic assumption that serial horizontal sections through the body are elliptical in shape, the area, a of each plane section of the photograph is given by

$$(1) \qquad a = \frac{\pi}{2} f \cdot s \quad \text{sq. mm.}$$

where f is the number of mm. in one-half the front view, and s is the

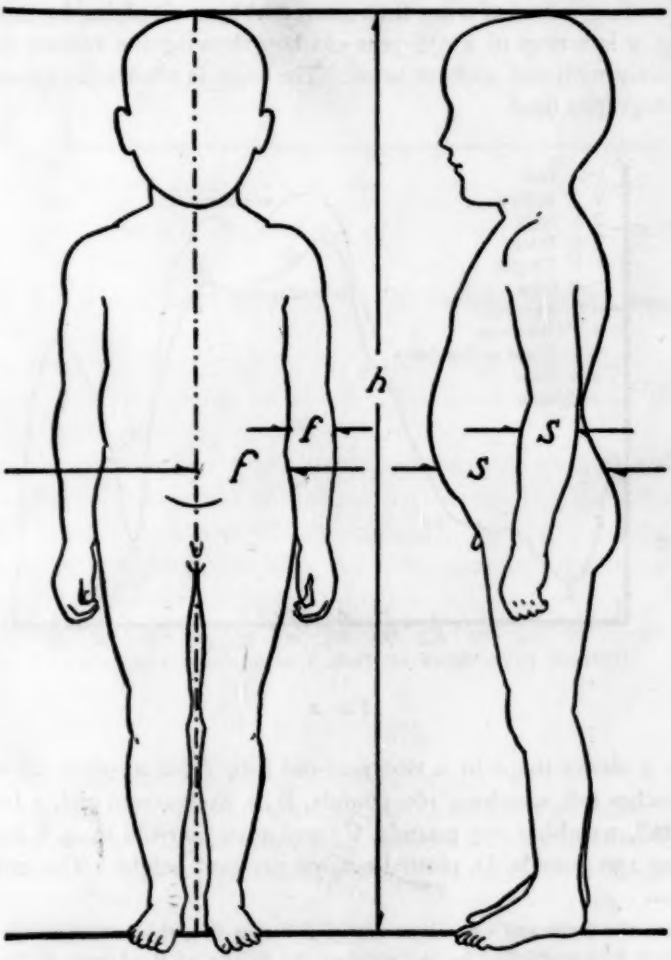

FIG. 1

number of mm. in the side view section.* Fig. 1 is a sketch for clarity of front and side views of a 3½ year old child, showing position of f and s.

If z denotes the height from the soles of the feet to the cross-section a (i.e. the point where f and s are measured), the volume contour map may be drawn by plotting a as ordinates against z as abscissae; or for comparison with other maps, the height z may be reduced to per cent height $100\ z/h$, where h is the height of the photograph in mm. The corresponding values of a are then converted by multiplying by $100^2/h^2$.

Fig. 2 is a map of a 3½-year-old boy showing the volume contour of the body with and without arms. The scale is arbitrarily taken from the photographs used.

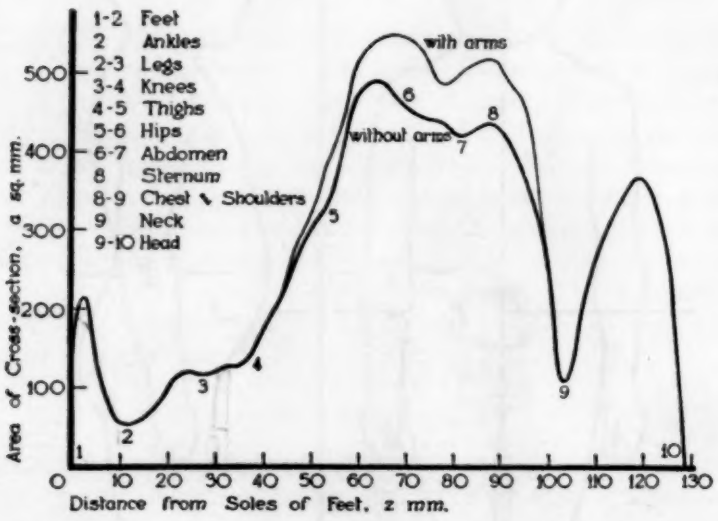

FIG. 2

Fig. 3 shows maps of a two-year-old girl, A; a 25-year-old man, 5 feet 7 inches tall, weighing 160 pounds, B; a 23-year-old girl, 5 feet 2½ inches tall, weighing 105 pounds, C; and a 26-year-old man, 6 feet tall, weighing 130 pounds, D, plotted against per cent height. The ordinates

* When the front and side views are of different size, the measurements on the smaller are first multiplied by the ratio of the height of the larger to the height of the smaller.

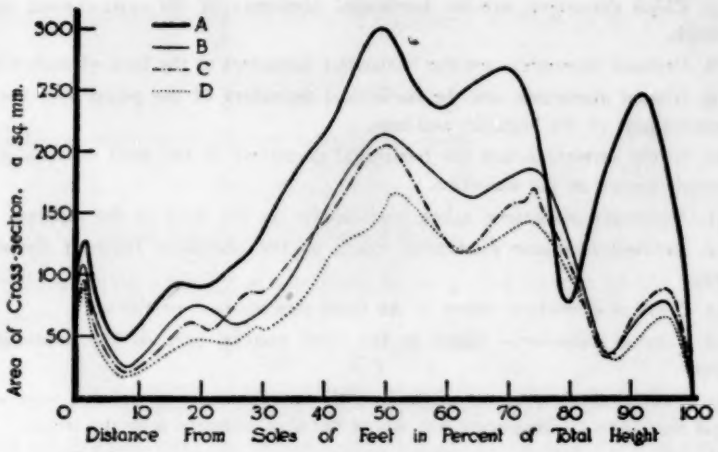

FIG. 3

of Fig. 3 are cross-sectional areas of the individual if his height was 100 mm.

The arms may be left out of the map to obtain the proper shape of the trunk, but they should be added in for determination of center of gravity or moment of inertia of the entire body.

The measurements of f and s are made with an accurate millimeter scale, and as many points as desired may be measured on the two pictures to give a smooth continuous contour map. However, it is generally only necessary to measure points that will give inflections in the map, such as the ankle, calf, knee, thigh, etc.

The following are points or diameters to measure on the photographs, suggested by Roussy's perimeters taken from Boyd (1):

DIAMETERS

1. *Plantar diameters*- are the horizontal diameters of the foot.
2. *Tibiotarsal diameters*- are the horizontal diameters of the ankle.
3. *Calf diameters*- are the diameters of the most convex part of the calf.
4. *Subpatellar diameters*- are the diameters of the leg at the most concave part just below the knee.
5. *Patellar diameters*- are the horizontal diameters at the knee cap.
6. *High patellar diameters*- are the diameters measured just above the knee at the most concave part of the thigh.

7. *Thigh diameters*- are the horizontal diameters of the most convex part of the thigh.

8. *Perineal diameters*- are the horizontal diameters at the base of each thigh.

9. *Gluteal diameters*- are the horizontal diameters of the pelvis over the most prominent part of the buttocks and hips.

10. *Girdle diameters*- are the horizontal diameters of the most concave part of the trunk known as the waistline.

11. *Mammary diameters*- taken horizontally on the chest at the nipples.

12. *Acromioclavicular diameters*- taken at the shoulders between the deltoid muscles.

13. *Cervical diameters*- taken at the most concave part of the neck.

14. *Coronal diameters*- taken at the most convex part of the forehead and occiput.

15. *Deltoid diameters*- taken horizontally at the most prominent part of the deltoid muscle to an imaginary line where the arm connects with the trunk.

16. *Elbow diameters*- taken at the elbow.

17. *Antebrachial diameters*- taken at the most convex portion of the forearm.

18. *Radiocarpal diameters*- taken at the wrist.

19. *Digital diameters*- taken at the palm of the hand.

These diameters may be measured directly on an adult or a cooperative child and the contour map plotted immediately. It is by no means necessary to adhere to the above list of diameters in measuring a photograph. Any number of measurements at any place on the body may be taken, and in fact, any irregularities in contour would call for more measurements.

Weight of the body. As a check on the preparation of the volume contour map, the weight of the body may be estimated from the completed map (i.e. one in which the arms are included). Since any cross-sectional area through the body may be thought of as an elemental volume, the volume of the photograph is given by the sum of these elements, or the area under the volume contour curve. By measuring the area under the curve, the volume of the photograph in cu. mm. or cu. cm. or cu. decm. is obtained.*

$$1000 \text{ cu. mm.} = 1 \text{ cu. cm.}$$

$$1000 \text{ cu. cm.} = 1 \text{ cu. decm.}$$

* A Keuffel and Esser Paragon planimeter No. 4240 was used to determine the areas under the curves.

The actual volume of the body in cu. decm. is then given by

$$V = v\frac{H^3}{h^3} \text{ cu. decm.} \tag{2}$$

where v = volume of photograph in cu. decm.

h = height of photograph in cm.

H = actual height of individual in cm.

Assuming the density of the body to be 1, the weight of the body in kilograms is

$$W = V \cdot 1 \text{ kg.} \tag{3}$$

Center of gravity. Assuming uniform density, the height of the center of gravity may be readily determined from the volume contour map. Fig. 4 illustrates the procedure: A second curve, marked Curve 2 in the figure, is drawn from the contour curve, marked Curve 1, by placing a straight edge connecting the origin 0 with various points such as C along the line AB and marking points at p_1, p_2, p_3 and p_4 which are the intersections of the vertical lines passing through the contour curve at the same point as the horizontal line through d_1, d_2, d_3 and d_4 with line 0C.

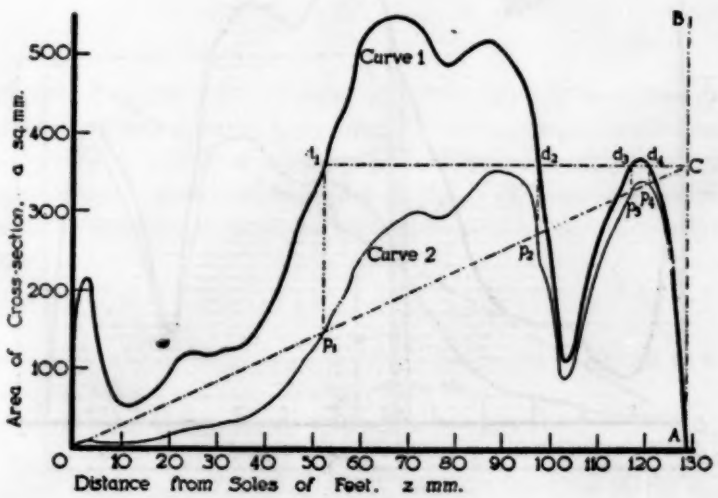

FIG. 4

The ratio of the area under Curve 2 to the area under the contour curve multiplied by the total abscissa length h gives the height of the center of gravity of the photograph.

$$\bar{z} = h \frac{A_2}{A_1} \text{ mm.} \tag{4}$$

or

$$\bar{z} = 100 \frac{A_2}{A_1} \text{ per cent} \tag{4a}$$

The actual height of the center of gravity of the body is then given by

$$\bar{Z} = \bar{z} \frac{H}{h} \text{ mm.} \tag{4b}$$

or, if the contour curve is plotted from direct measurements,

$$\bar{Z} = H \frac{A_2}{A_1} \tag{4c}$$

The general proof for equation (4) may be derived as follows: In Fig. 5, Curve 1 is the given contour curve for which the center of gravity is desired; Curve 2 is drawn from Curve 1 as previously described; h is the height of the given figure; A_1 is the area of the given figure, Curve 1; and A_2 is the area of the drawn figure, Curve 2.

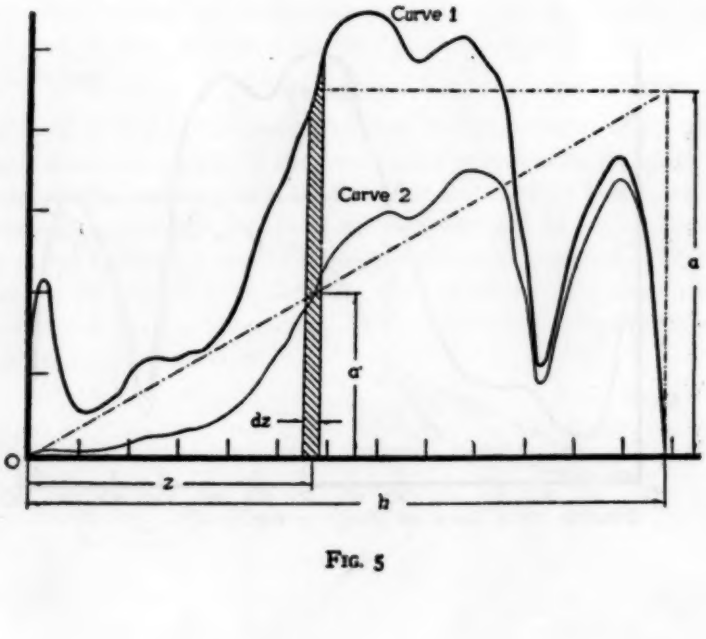

FIG. 5

The height of the center of gravity, $\bar{z}$, is given by

$$\bar{z} = \frac{\int z dA_1}{\int dA_1} \tag{5}$$

$$\bar{z} = \frac{1}{A_1} \int z dA_1 \tag{6}$$

but $\int dA_1 = \int a dz$, therefore

$$\bar{z} = \frac{1}{A_1} \int z a dz \tag{7}$$

By construction triangle Oa' is similar to triangle Oa, therefore

$$\frac{a'}{a} = \frac{z}{h} \tag{8}$$

$$ha' = az \tag{9}$$

Substituting ha' for az in equation (7)

$$\bar{z} = \frac{h}{A_1} \int a' dz \tag{10}$$

but $\int a' dz = \int dA_2$, therefore

$$\bar{z} = \frac{h}{A_1} \int dA_2 \tag{11}$$

$$\bar{z} = h \frac{A_2}{A_1} \tag{4}$$

Moment of inertia. The moment of inertia may also be readily determined for the limbs or entire body from the contour map. A third curve, marked Curve 3 in Fig. 6 is drawn from Curve 2 exactly as Curve 2 was drawn from Curve 1, as described in Fig. 4. The moment of inertia of the entire photograph about the soles of the feet as pivotal axis is then given by

$$i = h^2 A_3 \quad \text{cu. decm.-mm.}^2 \tag{12}$$

For comparison with other maps in which the height is plotted as a per cent, h in equation (12) may be replaced by 100.

$$i = 100^2 A_3 \tag{12a}$$

The actual moment of inertia of the body about the soles of the feet is then given by

(13) $$I = i\frac{H^5}{h^5} \text{ cu. decm.-mm.}^2$$

or

(13a) $$I = \frac{H^5}{h^3} A_3 \text{ cu. decm.-mm.}^2$$

which is numerically equal to the moment of inertia in kilogram-mm.^{2} assuming that the density of the body is 1.

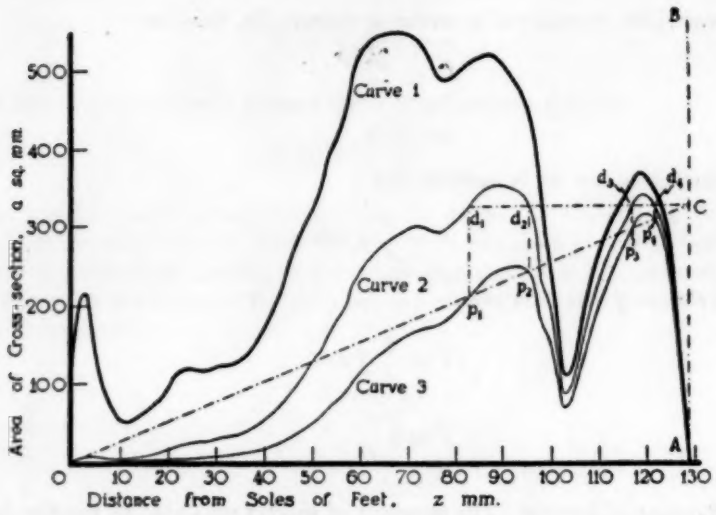

FIG. 6

If equation (12a) is used throughout a study of one individual, comparisons of relative changes in the moment of inertia may be made.

The general proof for equation (12) may be derived as follows: In Fig. 7 Curve 1 is the volume contour map for which the moment of inertia is desired; Curve 2 is drawn from Curve 1 as previously described; Curve 3 is drawn from Curve 2 in a similar manner; h is the height of the given figure; A_1, A_2 and A_3 are the areas under Curves 1, 2, and 3 respectively. By construction triangle Oa' is similar to triangle Oa, therefore

(14) $$\frac{a'}{a} = \frac{z}{h}$$

Triangle Oa'' is similar to triangle Oa', therefore

$$\frac{a''}{a'} = \frac{z}{h} \tag{15}$$

$$a'' = \frac{a'z}{h} \tag{16}$$

$$a' = \frac{az}{h}$$

Therefore

$$a'' = \frac{az^2}{h^2} \tag{17}$$

and

$$z^2a = a''h^2 \tag{18}$$

The moment of inertia about the soles of the feet is then given by

$$i = \int z^2 dA_1 \tag{19}$$

but $\int dA_1 = \int a dz$, therefore

$$i = \int z^2 a dz \tag{20}$$

Substituting $a''h^2$ for z^2a from equation (18) in equation (20)

$$i = h^2 \int a'' dz \tag{21}$$

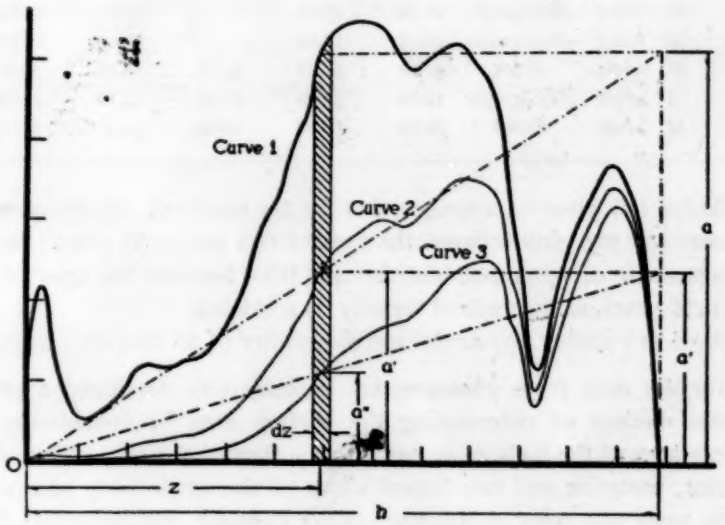

FIG. 7

but $\int a^n dz = \int dA_s$, therefore

(22) $$i = k^2 \int dA_s$$

(12) $$i = k^2 A_s$$

Table 1 gives a few examples of volumes of the body obtained by photographs or direct measurement, and a comparison of the volumes in cubic decimeters with the weight in kilograms. Center of gravity and moment of inertia are also given. In general, the center of gravity remains constant with age while the relative moment of inertia decreases with age.

TABLE 1

NAME	SEX	AGE	METHOD	WEIGHT	VOLUME	VOLUME X 1.037	CENTER OF GRAVITY	RELATIVE MOMENT OF INERTIA
		days		kg.	decm.³	adults only	% height	decm.³–mm.²
J.S.	M	494	photograph	12.24	12.29	....	55.39	78.40
C.C.	F	908	photograph	12.68	12.13	....	53.94	58.49
L.DR.	M	951	photograph	13.01	13.30	....	54.93	66.04
R.N.	F	1163	photograph	16.20	15.62	....	53.21	57.89
J.W.	M	1283	photograph	16.55	17.24	....	56.09	65.74
K.W.	F	adult	direct	47.62	45.62	47.31	54.33	39.31
K.B.	M	adult	photograph	52.60	50.46	52.33	53.16	36.09
A.W.	M	adult	direct	61.22	58.82	61.00	54.50	32.67

Basler (3) gives an average value for the center of gravity of 56.62 per cent for 507 girls between the ages of 6½ and 17½ years; and an average value of 57.11 per cent for 438 boys between the ages of 6½ and 14½ years, as determined directly on a balance.

Boyd (1) gives 1.037 as the specific gravity of an average size man.

Surface area from photographs. Roussy (2) developed a photographic method of determining the surface area by considering the surface area of the body to be equal to the sum of the silhouettes of the anterior, posterior and two lateral views of the whole body plus views of the arms and soles of the feet. Also Benedict, quoting from Boyd (1),

.....obtained three sharply outlined silhouettes of fourteen men and six women of diverse body build by photographing them standing between a window and a sheet. The area of each silhouette was measured with a planimeter and corrected for photographic reduction. Since the ratios of the surface areas as estimated by the Du Bois linear method to the areas of the silhouettes were found to vary less for the lateral view with the arms extended forward than for the lateral view with the arms at the side or for the anteroposterior view with the arms akimbo, the surface area of other subjects could be best estimated from their silhouettes in the first position.... If the Du Bois linear method is assumed to give the correct surface area, this silhouette technique would give the surface area within an average experimental error of 1.6 per cent and a range of —2 to +5 per cent.

The preparation of a surface contour map is mathematically a more rigid method of obtaining the surface area than either Roussy's or Benedict's estimates.

To obtain the surface contour map a curve must be drawn using perimeter measurements as ordinates, instead of cross-sectional areas used in preparing the volume contour map. Assuming that horizontal sections through the body are elliptical in shape, the perimeter of any section of the trunk of the photograph is given approximately by*

$$p = \pi \left(f + \frac{s}{2}\right) \cdot 1.03 \text{ mm.} \tag{23}$$

while the sum of the perimeters of the legs or the arms is given by

$$p = \pi (f + s) \cdot 1.03 \text{ mm.} \tag{23a}$$

where f = one-half the front view
s = the side view
p = the perimeter

* A closer approximation is given by

$$p = \pi \left(f + \frac{s}{2}\right) k$$

where $k = 1 + \frac{1}{4}m^2 + \frac{1}{64}m^4 + \frac{1}{256}m^6 + \ldots\ldots$

and $m = \dfrac{f - \frac{s}{2}}{f + \frac{s}{2}}$

For

m	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
k	1.002	1.010	1.023	1.040	1.064	1.092	1.127	1.168	1.216	1.273

The surface contour map is plotted in similar manner to the volume contour map, plotting p as ordinates against z, the height from the soles of the feet of the perimeter p (the point where f and s are measured), against z as abscissae. Fig. 8 is such a plot.

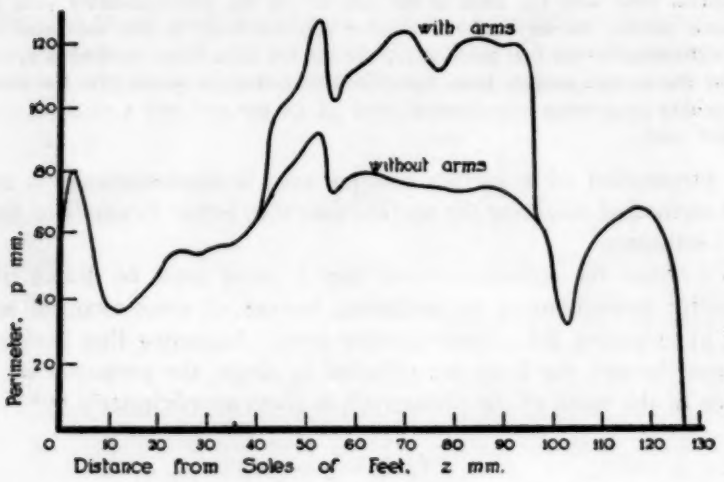

FIG. 8

Since the perimeter at any section of the body may be thought of as an elemental strip of surface, the total surface of the body would be given by the summation of these elemental strips, or the area under the surface contour map.

Surface area from direct measurements. It must be pointed out here that equation (23) for the perimeter from measurements of two diameters is only an approximation and that more accurate estimations of surface area can be obtained by actually taking the perimeters at various points on the body.

Roussy's perimeters (1) are suggested points to measure:

Perimeters

1. *Coronal perimeter* passes almost horizontally around the most convex part of the forehead and occiput.

2. *Menton perimeter* passes around the point of the chin, along the inferior border of the lower jaw to its angle, and horizontally around the neck.

3. *Cervical perimeter* commences on the thyroid eminence and takes an almost horizontal course on the most concave part of the neck.

4. *Acromioclavicular perimeter* passes along the anterior border of the clavicles and turns back around the point of the acromion.

5. *Mammary perimeter* is taken horizontally around the chest across both nipples.

6. *Girdle perimeter* is the circumference of the most concave part of the trunk, the waistline.

7. *Gluteal perimeter* passes around the pelvis over the most prominent part of the buttocks and hips.

8. *Perineal perimeter* is taken at the base of each thigh, passing into the gluteal fold and touching the perineum.

9. *Patellar perimeter* passes horizontally around the kneecap with the leg extended in the standing position.

10. *Subpatellar perimeter* is the circumference of the leg at the most concave part.

11. *Calf perimeter* is the horizontal circumference of the most convex part of the calf.

12. *Tibiotarsal perimeter* passes over the tibiotarsal articulation, or ankle.

13. *Plantar perimeter* is the horizontal circumference of the foot in the standing position.

14. *Scapulohumeral perimeter* is taken around the scapulohumeral articulation of the extended arm.

15. *Elbow perimeter* passes over the point of the elbow.

16. *Antebrachial perimeter* is taken around the most convex part of the forearm.

17. *Radiocarpal perimeter* is taken around the radiocarpal articulation, or wrist.

18. *Digital perimeter* is taken around the palm of the hand.

Any number of perimeters may be taken as desired, care being taken to measure the height from the soles of the feet of any perimeter. The surface contour is then made by plotting the perimeters as ordinates against their heights from the soles of the feet as abscissae. The area under this curve then gives the total surface of the body.

SUMMARY

Volume contour maps from photographs.—

1. Measure height and weight of individual.
2. Take front and side view photographs and enlarge.
3. With accurate millimeter scale, measure one-half the front view horizontally with picture erect and the side view, at various points on the body.

4. Multiply front and side measurements together, times 3.1416/2.
5. Plot values from 4 as ordinates against their heights from the soles of the feet as abscissae.

Volume contour maps from direct measurements.—

1. Measure height and weight of individual.
2. Measure diameters at foot, ankle, calf, patella, thigh, buttocks and hips, waist, shoulders, neck, head, deltoids, elbow, forearm, wrist, hand and any others which seem necessary.
3. Multiply measurements of diameters together times 3.1416/2.
4. Plot values obtained from 3 as ordinates against the height of each measurement from the soles of the feet.

Center of gravity from volume contour map.—

1. Construct a second curve from the volume contour map as described.
2. Measure the areas of the second curve and the contour curve.
3. The center of gravity is given by the product of the height times the ratio of the area of the second curve to the area of the volume contour curve.

Moment of inertia from volume contour map.—

1. Construct a third curve from the second curve as described.
2. Measure the area of the third curve.
3. The moment of inertia about the soles of the feet is given by the product of the height squared times the area under the third curve.

Surface area from photographs.—

1. Obtain perimeters at various points along the photograph.
2. Prepare a surface contour map by plotting the perimeters as ordinates against their heights from the soles of the feet as abcissae.
3. The total surface of the body is given by the area under the contour map times the ratio of the actual height of the individual squared to the height of the photograph squared.

Surface area from direct measurements.—

1. Obtain perimeters at various points along the body.
2. Prepare a surface contour map.

3. The total surface of the body is given by the area under the contour map.

The volume, center of gravity, moment of inertia or surface area of any of the parts of the body may be obtained from the maps by treating the desired part as described for the entire body.

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THE EFFECT OF CONTRACEPTION UPON HUMAN FERTILITY*

BY GILBERT W. BEEBE AND CLARENCE J. GAMBLE, M.D.

INTRODUCTION

DIFFERENTIAL fertility and decreases in rates of population growth encourage an examination of their biological basis. Of the a priori possibilities, voluntary limitation of offspring by means of contraceptives is generally accorded recognition as the major biological factor involved. It is, therefore, of considerable demographic importance to gather material bearing on the use and effectiveness of various contraceptive methods. The recent contributions of Pearl[1] and of Stix and Notestein[2] provide a methodology for the quantitative treatment of such data, and report a valuable body of pertinent, factual information.

The present report continues an earlier study[3] which gave the results of a follow-up of 83 patients who had accepted contraceptive advice at

* From the National Committee on Maternal Health, Inc. Two East 103rd Street, New York City.

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a Philadelphia general hospital. In 1933 the obstetrical department commenced experimentation with the routine offering of contraceptive advice to all postnatal patients approximately one month postpartum. This action was based upon a desire to facilitate the spacing of births, rather than upon a responsibility to patients presenting the more important medical contra-indications to pregnancy. For this reason, and in the hope that a simpler method would be more acceptable and hence more effective in reducing aggregate fertility, it was decided to offer a water dispersible, lactic acid (2 per cent) and vegetable gum contraceptive jelly to those postnatal patients who wished it, and who would pay the cost of the materials, twenty cents for a tube of jelly and ten cents for a nozzle. Patients were not directed to use jelly alone, but this possibility was strongly suggested, and additional information was given on the greater effectiveness of the condom plus jelly, on the least fertile period of the menstrual cycle, and also on the possibility of attending a diaphragm clinic for a fitting.

The preliminary report gave a pre-hospital fertility rate of 69 pregnancies per 100 person-years of exposure, and a post-hospital rate of 10 for undesired pregnancies. The data did not permit an analysis according to the individual contraceptive methods used, but a classification of patients into regular users, intermittent users, and non-users made it clear that the unfailing use of the jelly was associated with the most marked fertility reduction.

In order to measure more accurately the impact of the hospital experience upon the fertility of the selected patients, and to differentiate among the several contraceptive methods employed, both before and after the hospital contact, a more extensive study was undertaken a year later with all cases of more than six months' duration which could be located. A detailed schedule in the hands of Miss Helen Carson, a skilled social worker, secured from each of 197 patients a complete reproductive and contraceptive history, and certain supplementary characteristics which included religion, education, and occupation. The results of this second study are presented in this report.

CHARACTERISTICS OF THE GROUP

The cases obviously constitute a selected group. All are white and of demonstrated fertility. Moreover, they possessed sufficient interest in family limitation to make the small payment for contraceptive materials. Although all the hospital patients receiving supplies were not studied,

there seems no reason to expect that the results are distorted by the omission of those who had moved out of the Philadelphia area or to an untraceable address. Despite its size, the sample is fairly homogeneous. The occupational distribution of husbands is presented in Table 1, the basis of the classification being that of Edwards[4]. The percentage distributions for Protestants and for Catholics are almost identical and are therefore omitted from the table.

TABLE 1

Distribution of patients by occupation of husband

OCCUPATIONAL GROUP	PATIENTS	
	Number	*Per cent*
A. Mainly clerical workers	28	14
B. Skilled workers and foremen	84	43
C. Semiskilled and unskilled workers	78	40
D. Unspecified	7	3
TOTALS	197	100

The educational distribution is presented in Table 2 for the two religious groups, since they lacked homogeneity in this respect.

The mean age at marriage was 20.2 for both Protestants and Catholics, with very little difference for the major educational and occupational groups, except that the Catholic semiskilled and unskilled had a mean age of 17.6 as contrasted with 20.7 for the Protestants. The mean number of years married at the time of the contraceptive consultation was 6.45 for the whole sample, 6.8 for Protestants, and 6.1 for

[4] Edwards, Alba M. A social economic grouping of the gainful workers of the United States. *Jour. Amer. Stat. Assn.*, 28:377-387, December, 1933. The Edwards grouping is: (1) Professional persons; (2) Proprietors, managers and officials; (3) Clerks and kindred workers; (4) Skilled workers and foremen; (5) Semiskilled workers; (6) Unskilled workers. In the present report these six groups have been combined into three: A includes 1-3, B is 4, and C represents 5 and 6.

TABLE 2

Educational distribution by religion of wife at time of follow-up

GRADES COMPLETED BY WIFE	TOTAL		PROTESTANTS		CATHOLICS	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
1-4	2	1	1	1	1	1
5-8	128	65	54	56	74	73
9-12	62	31	38	40	24	24
Other, or unspecified	5	3	3	3	2	2
TOTALS	197	100	96	100	101	100

Catholics. The educational group with but 5 to 8 years of schooling had been married, on the average, for 7.2 years, while the group with some high school training had a mean duration of marriage of 4.65 years, religious differences being minor. The mean number of pregnancies at the time of purchasing the jelly was 2.7 for the whole group, 2.5 for Protestants, and 2.8 for Catholics.

METHODS OF MEASUREMENT

The statistical techniques formulated by Pearl[5] and developed in part by Stix and Notestein[6] follow the accepted practice in vital statistics by relating the incidence of the phenomenon under observation to the population undergoing the risk during a specified time interval. As used in this study, this amounts to the calculation of a pregnancy rate per 100 woman-years of exposure to the risk of pregnancy. The concept of exposure to the risk of pregnancy has been defined by Pearl and by Stix and Notestein as that period in a woman's married life when she may be presumed to be fecund, i.e. is not already pregnant, has no physical basis for infecundity, and is not practicing abstinence. In calculating exposure any reported months of abstinence or separation have been subtracted, and for each pregnancy a deduction of one month in excess of the reported period of gestation has been made to cover the

[5] Pearl, Raymond. *Op. cit.*

[6] Stix, Regine K., and Notestein, Frank W. *Op. cit.*

puerperium. Since no satisfactory method has been worked out for deducting infertility resulting from the absence of ovulation following parturition and associated with lactation, calculating exposure from one month postpartum tends to underestimate fertility to the extent that the protection from lactation is real. Pregnancy rates for contraceptive exposure tend to measure the biological effectiveness of the contraceptive methods plus the skill and faithfulness with which they are employed. Rates for non-contraceptive exposure approximately measure fecundity modified by pathology and frequency of coitus. In general, rates are presented for exposure without contraception, for exposure with contraception of any variety, and for exposure with specific methods of contraception.

CONTRACEPTION AND FERTILITY BEFORE HOSPITAL INSTRUCTION

Extent of reliance upon contraception. In recording the reproductive history the social worker questioned the patient on the use of contraception before each pregnancy, and the type (including withdrawal) which was employed. While complete accuracy of the patient's memory is not to be expected, any resulting errors should have a chance distribution which would not prejudice the results.

Table 3 gives in percentage form the ratio of time spent practicing contraception to total exposure, by order of pregnancy, and by religion.

TABLE 3

Months of pre-hospital exposure classified as contraceptive, by religion, and by order of pregnancy

RELIGION	EXPOSURE BEFORE FIRST PREGNANCIES			EXPOSURE BEFORE SECOND AND SUBSEQUENT PREGNANCIES		
	Total	*Contra-ceptive*	*Percentage Contraceptive*	*Total*	*Contra-ceptive*	*Percentage Contraceptive*
Protestant	1219	460	*38*	3199	2150	*67*
Catholic	974	189	*19*	3812	2524	*66*

Since both religious groups were selected for their interest in contraception, their similarity after their first pregnancies is not surprising, but the difference before the first pregnancy is noteworthy.

A broad occupational grouping, such as that employed in Table 4, indicates that the white-collar workers had practiced contraception less before their first pregnancies, and more thereafter, than had the laboring group.

TABLE 4

Months of pre-hospital exposure classified as contraceptive, by occupation, and by order of pregnancy

OCCUPATIONAL GROUP	EXPOSURE BEFORE FIRST PREGNANCIES			EXPOSURE BEFORE SECOND AND SUBSEQUENT PREGNANCIES		
	Total	*Contraceptive*	*Percentage Contraceptive*	*Total*	*Contraceptive*	*Percentage Contraceptive*
A. Mainly clerical workers.....	501	94	*19*	903	739	*82*
B. Manual workers.....	1692	555	*33*	6108	3935	*64*

Relative dependence upon specific contraceptive methods. The proportion which exposure with a specific method bears to the total contraceptive exposure is perhaps the best single measure of the rôle a method plays in contraception. Table 5 gives the contraceptive exposure classified according to the methods alleged to have been used.

The three most common methods, used alone, account for 73 per cent of the total contraceptive exposure. They also comprise 75 per cent of the exposure classified under methods used alternately and 68 per cent of the exposure for methods used simultaneously. Hence their total relative importance may be stated as 91 per cent of the total prehospital contraceptive effort. The relative frequency for the category made up largely of methods used alternately should be of significance to the clinician, for it testifies to the diversity of present contraceptive practice and foreshadows difficulty with the routine prescription of a single present method.

Effects of contraceptive practice upon fertility. If the pregnancy rates for exposure without contraception be taken as the standard, then it is clear that the practice of contraception in this group of 197 urban,

TABLE 5

Classification of pre-hospital contraceptive exposure by type of contraception employed

CONTRACEPTIVE METHOD	MONTHS OF CONTRACEPTIVE EXPOSURE	
	Number	*Per cent*
Withdrawal alone	1,315	25
Douche alone	1,480	28
Jelly alone	85	1
Condom alone	1,045	20
Others used alone, and any used alternately	1,212	23
Any used simultaneously	186	3
TOTAL	5,323	100

postnatal patients reduced their fertility by roughly 60 per cent in the pre-hospital period. Table 6 presents the pregnancy rates essential for this comparison, together with those for specific contraceptive methods. The latter furnish an index to the effectiveness of the methods as used, and indicate that the condom gave the highest protection in the pre-hospital experience.

CONTRACEPTION AND FERTILITY AFTER HOSPITAL INSTRUCTION

Fertility reduction. Striking reductions in fertility followed the process of selection and contraceptive consultation at the hospital. The fact that all cases were postnatal suggests that lactation may have been present in the post-hospital period to a greater relative extent than in the pre-hospital period. If so, the partial protection it is thought to afford may have implemented the reduction in fertility shown in Table

[7] The differentiation between rates for first and rates for all other pregnancies follows from the recognition that rates for first pregnancies tend to be significantly higher than rates for second and subsequent pregnancies, perhaps because of the interference of lactation. In this table, as in similar tables throughout this report, first pregnancy exposure means exposure up to the first conception. Second and subsequent pregnancy exposure includes all that follow the termination of the first pregnancy.

TABLE 6

Months of exposure, pregnancies, and pregnancy rates in the pre-hospital period, by contraceptive practice, and by order of pregnancy[1]

CONTRACEPTIVE PRACTICE	ALL PREGNANCIES			FIRST PREGNANCIES			SECOND AND SUBSEQUENT PREGNANCIES		
	Expos.	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
All exposure	9204	505	66	2193	181	99	7011	324	55
Without contraception	3881	320	99	1544	153	119	2337	167	86
All contraception	5323	185	42	649	28	52	4674	157	40
Withdrawal	1315	40	37	89	5	**	1226	35	34
Douche	1480	70	57	136	12	106	1344	58	52
Condom	1045	19	22	195	5	31	850	14	20
All other methods	1483	56	45	229	6	31	1254	50	48

* Pregnancies per 100 woman-years of exposure.
**Less than 100 months of exposure.

7. At its maximum, however, the influence of lactation would not be great, for the arbitrary exclusion of six additional months from the post-hospital exposure for each case, 1182 months in all, raises the rate from 12 to only 18. Moreover, 8 of the 38 unplanned pregnancies began less than 7 months after parturition. A rate may therefore be based on the period beginning 7 months postpartum. The fact that this rate [(30/2500) × 1200] is 14, is fair evidence that lactation had no considerable influence on the post-hospital rate of those in this group who relied upon contraception. This conclusion also receives support from the observation that the post-hospital rate while using no contraception is no lower than the corresponding rate in the pre-hospital period.

TABLE 7

Months of exposure, pregnancies, and pregnancy rates for second and subsequent pregnancies, before and after the hospital selection and advice, by type of exposure

TYPE OF EXPOSURE	PRE-HOSPITAL			POST-HOSPITAL		
	Expos.	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**
All exposure.....	7011	324	55	3911	56	17
Without contraception.....	2337	167	86	229	18	94
With contraception.....	4674	157	40	3682	38	12

* Pregnancies per 100 woman-years of exposure.

Equally pronounced were the reductions in pregnancy rates specific by method of contraception, as Table 8 illustrates. Two contributing factors should be noted. In the first place, influenced by criticism of contraceptive procedure, patients who had previously used methods which had failed, tended to abandon them for more effective methods while those who had been successful with former methods often continued with them. Secondly, specific methods probably shared a general improvement in technique and in regularity of use prompted by the proximity of parturition, for these patients were selected for their postnatal interest in contraception.

TABLE 8

Months of exposure, pregnancies, and pregnancy rates before and after the hospital selection, by method of contraception, for second and subsequent pregnancies

METHOD	PRE-HOSPITAL[a]	POST-HOSPITAL		
	Rate[b]*	*Expos.*	*Preg.*	*Rate*[b]*
All methods	40	3682	38	12
Withdrawal alone	34	445	1	3
Douche alone	52	237	6	30
Jelly alone	**	726	9	15
Condom alone	20	946	6	8
All others	48	1328	16	14

[a] These rates are from column 10, Table 6.
[b] Pregnancies per 100 woman-years of exposure.
**Less than 100 months of exposure.

In the preliminary study[8] of 83 cases, the absence of detailed information on methods of contraception supplementary to the jelly made possible only a classification of jelly users into Group I, regular and careful users, and Group II, irregular users or those who discontinued. The pregnancy rates for undesired pregnancies were found to be 4 and 9 for these two groups in the preliminary report. The more extensive data provided by the second follow-up permitted a calculation of the rates for jelly alone for these two groups.[9] These rates are 5 (1 pregnancy in 221 months of exposure) and 12 (2 pregnancies in 197 months of exposure), not essentially dissimilar from the rates first reported for all contraceptive practice. The fact that the second study yields the higher value of 15 for jelly alone may well result from a higher proportion of careless users in the larger sample.

[8] Gamble, C. J. and Beebe, G. W. *Op cit.*, p. 82.
[9] All but two patients in the original Group I, and two patients in Group II were found in the second follow-up.

When the pre-hospital and post-hospital periods are compared the conclusion seems fair that the jelly, used alone or with condom, added to the methods already known to the patients, and together with a new emphasis on the value of the condom, served to depress greatly the fertility of the entire group of patients for the period under review, approximately 21 months after parturition. An important factor in the fertility reduction would seem to have been a greater determination to avoid immediate pregnancy than previously, since the lower pregnancy rates for individual methods suggest more careful use. The post-hospital protection attained with coitus interruptus seems remarkable and is probably an extreme instance of the selection of a method well adapted to the individual. Under the circumstances, only those with experience and fair success with the method could feel confident enough to continue its use.

Effects of standardization and grouping by age upon pregnancy rates.

Throughout this study crude rates have been used for comparative purposes. It is well known that lack of homogeneity with respect to such basic variables as age often makes crude rates untrustworthy guides to interpretation. The difference between any two pregnancy rates, for example, might result solely from an age differential, or an order of pregnancy differential. To overcome this difficulty the usual practice is to employ rates specific by the variable to be controlled, or to standardize the data to be compared against a standard distribution of the variable in question. In this study the homogeneity of the age distributions has been tested by the computation of standardized rates.[10] Both age and duration of marriage distributions gave standardized rates which differed little from the crude rates, and therefore the simpler rates have been employed.

TABLE 9

Months of exposure, pregnancies, and pregnancy rates, by order of

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[10] As may be seen from Table 9, pregnancy rates were computed specific by age and by duration of marriage, using five-year intervals. The standardized rate is that which would obtain if each interval provided the same proportion of exposure as exists in a standard distribution of exposure. The following expression has been used:

$$\text{Standardized rate} = \Sigma\left(\frac{P}{E} \times E'\right) \times \frac{1200}{\Sigma E'}$$

where P represents the number of pregnancies observed, E the number of months of exposure observed, and E' the number of months of exposure in the hypo-

TABLE 9

Months of exposure, pregnancies, and pregnancy rates, by order of pregnancy, by type of exposure, and by 5 year duration of marriage and age intervals

ORDER OF PREGNANCY, AND FIVE YEAR AGE OR MARRIAGE INTERVALS	PRE-HOSPITAL						POST-HOSPITAL					
	Without contraception*			*With contraception*			*Without contraception*			*With contraception*		
	Expos.	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**	*Expos.*	*Preg.*	*Rate**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
First pregnancies....	1544	153	*119*	649	28	*52*	...	..	...	....	..	..
Second and Subsequent pregnancies												
A. *Duration of marriage*												
0-4 years.....	1085	90	*100*	1934	64	*40*	102	11	*129*	1481	14	*11*
5-9 "	795	53	*80*	1668	58	*42*	54	4	**	1088	14	*15*
10-14 "	363	16	*53*	815	23	*34*	32	3	**	655	6	*11*
15-19 "	94	8	**	235	11	*56*	37	0	**	398	4	*12*
20-29 "	....	...	...	22	1	**	4	0	**	60	0	**
B. *Age*												
15-19 "	186	16	*103*	433	10	*28*	28	5	**	178	1	*7*
20-24 "	892	69	*93*	1568	55	*42*	62	6	**	1141	16	*17*
25-29 "	733	50	*82*	1524	49	*39*	40	2	**	1002	10	*12*
30-34 "	437	27	*74*	861	30	*42*	46	4	**	817	7	*10*
35-44 "	89	5	**	288	13	*54*	53	1	**	544	4	*9*

* The non-contraceptive exposure includes a small amount of planning for conception, the deduction of which would lower the rates somewhat without altering the trend.

* Pregnancies per 100 woman-years of exposure.

**Less than 100 months of exposure.

Age and duration of marriage as factors in the decline in fertility. Rates specific by duration of marriage or by age show chance fluctuations due to paucity of data, but the indications of Table 9 are, in general, that fertility declines as patients enter the upper age or duration of marriage intervals. This is so despite the fact that the selection of the older women in the present sample is based upon fertility late in life. Lest such findings be taken to indicate that fecundity declines with age, it is perhaps useful to point to the findings of Stix and Notestein[11] for temporary non-contraception for planned pregnancy. They found that rates for temporary non-contraception were well sustained throughout the first 15 years of married life, although their rates for habitual non-contraception showed a decline similar in trend to that of Table 9. Unfortunately the amount of temporary non-contraception for planned pregnancy furnished by the present series is too small for analysis.

TABLE 10

Manner of using jelly purchased from hospital

HOW USED	REPORTS	
	Number	*Per cent*
Alone	86	64
Simultaneously with condom	17	12
Alternately with condom	13	10
Alternately with withdrawal	6	4
Otherwise	13	10
TOTAL	135	100
TOTAL PATIENTS	128	

thetical or standard distribution, for any five-year duration of marriage or age interval. In standardizing age rates the age distribution of all exposure (Table 9, Columns 2 plus 5 for first pregnancies and for subsequent pregnancies through B) was employed, while the duration of marriage rates were standardized against the duration of marriage exposure (Table 9, Columns 2 plus 5 for first pregnancies and for subsequent pregnancies through A).

[11] Stix, Regine K., and Notestein, Frank W. *Op. cit.* Second report, p. 168.

Social psychological factors in the hospital experiment. One hundred and twenty-eight patients, or 65 per cent of the total number followed up, used the jelly purchased, and 95 patients, or 74 per cent of those who tried it, discontinued its use. Table 10 shows how they made use of the jelly in their contraceptive efforts.

Of 130 reports on the fraction of exposures for which the jelly was used (alone or in combination), 20 stated that jelly had been used less than half the time, 19 half the time or more, but not all the time, and 91, or 70 per cent, all the time. Of the 95 patients who had discontinued the jelly at the time of follow-up, and whose alleged reasons for stopping are set forth in Table 11, 65 patients, or 68 per cent, had stopped within 6 months of purchasing the jelly.

TABLE 11

Alleged reasons for stopping the use of jelly, regardless of how used

REASON GIVEN	REPORTS	
	Number	*Per cent*
Exhaustion of materials	32	21
Lack of confidence	28	18
Too much trouble to use	22	14
Messiness of materials	18	12
Preference for another method	12	8
Renewal of supplies at hospital too difficult	11	7
Exposure ceased with conception	11	7
Stopped for planned pregnancy	5	3
Ignorance of technique of use	4	2
Jelly caused burning	3	2
All other reasons	9	6
TOTAL REPORTS	155	100
TOTAL PATIENTS	95	

In retrospect, and in the opinion of the investigator making the follow-up, it seems clear that the variety of information and advice given to each patient militated against consistent use of jelly. In failing to build confidence in any one method, the service prevented some from making any use of the material purchased, and others from continuing

its use once begun. Of the 69 patients who purchased jelly and who never use it, 36 patients, or 52 per cent, declared their distrust of the material, while 17 evinced preference for other methods.

SUMMARY

Information secured from the 197 accessible members of a selected group of fertile, white women who received postnatal contraceptive advice from an urban hospital is reported for its bearing on the accumulation of data through more accurate studies in fertility and contraception.

The analysis is based upon 767 woman-years of exposure to the risk of pregnancy and 505 pregnancies before the hospital consultation, and upon 326 woman-years of exposure with 56 pregnancies following the consultation. Among the findings for this small sample were the following:

1. Protestants practiced contraception twice as much as Catholics before the first pregnancy, after which the proportions were virtually identical.

2. White-collar workers, mainly clerical, practiced contraception less than the manual workers before the first pregnancy, and more thereafter.

3. Whether exposure and pregnancies are grouped by duration of marriage or by age, there is a clear inverse association between age and pregnancy rates while using no contraception, but this observation is to be qualified by the fact that the rates reflect primarily habitual non-contraception.

4. Withdrawal, douche, and condom, each used alone, accounted for 73 per cent of the total pre-hospital effort. Used alternately, in combination, or alone, they constituted 91 per cent of the contraception in this period.

5. Pre-hospital contraceptive practice reduced fertility by approximately 60 per cent, with the condom furnishing the highest protection, a fertility reduction of 78 per cent.

6. The process of selection for fertility and postnatal interest in contraception, and the consultation at the hospital, prefaced a reduction in total fertility of 70 per cent.

In comparison with the pre-hospital non-contraceptive rate of 86 pregnancies per 100 person-years of exposure for second and subsequent pregnancies, the 307 woman-years of post-hospital contraceptive ex-

posure showed a rate of 12, a fertility reduction of 86 per cent. Percentage reductions for the individual methods were: withdrawal 97, condom 91, jelly 83, douche 65, all others 84.

7. Thirty-five per cent of those patients who purchased jelly, and who were found on follow-up, had never used the jelly. Seventy-four per cent of those who tried it stopped before the date of the follow-up. The supposition is made that the variety of information and suggestions presented to the individual patient confused her and failed to give her confidence in any one method or combination of methods.

DEPRESSIONS, WEATHER AND HEALTH

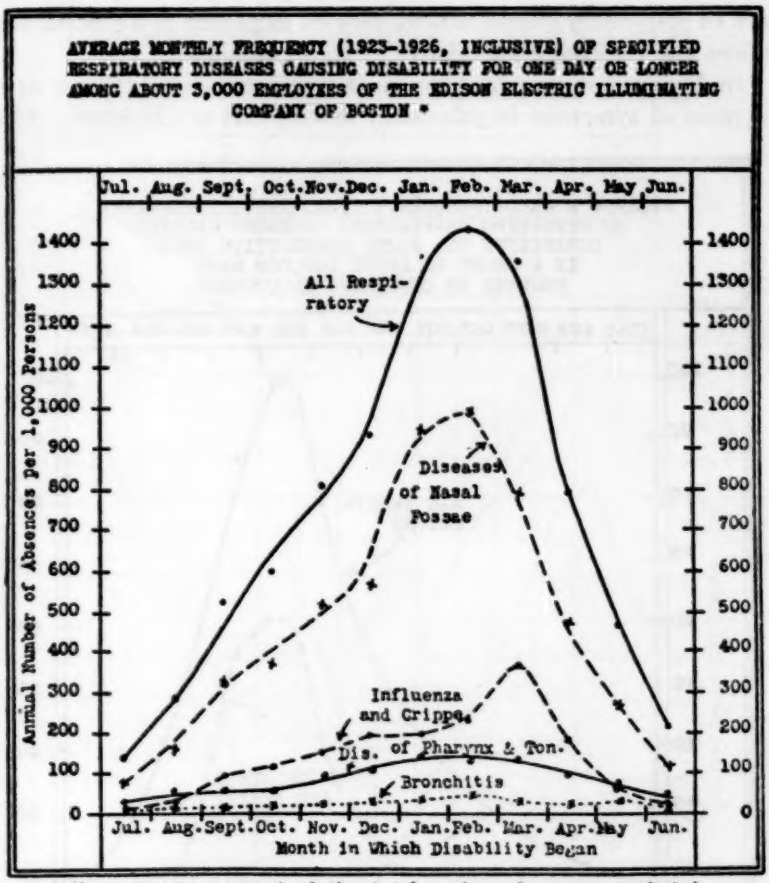
BY CLARENCE A. MILLS, M.D., PH.D.

Professor of Experimental Medicine, University of Cincinnati

PHYSICIANS in any population mass should be most familiar with the general health of the people among whom they practice, and should be well aware of health trends and of generally-acting factors that affect the physical welfare of the mass. And yet, how much does the average—or better than average—physician comprehend of the health changes that accompany our alternating periods of prosperity and economic depression? He accounts for the decline in calls for his services during hard times on the basis of restricted family or individual incomes, overlooking entirely the fact that general death rates are lowest in those same years when there are fewest calls for medical aid. Can it be that calls for a physician's help actually increase the risk of death!

There are fundamental and important factors at work in these health and economic cycles, factors which are here analyzed and set forth because of their direct and immediate bearing on the general health of the population mass. General health does, beyond a doubt, improve during prolonged depression periods and it declines during prosperity. But why? These health changes occur in spite of reduced use of medical aid in hard times and more frequent calls on physicians in good years, and hence can be little influenced by the medical profession (unless its activities constitute a real health handicap).

Since these depression and prosperity changes in general health now seem basically related to changes in earth temperatures and storminess, let us first examine the health changes that come with the more familiar seasonal swing in these weather factors. We of the north temperate zone are aware of the marked seasonal tide in health, of the increased dangers that come with the cold and storms of winter and the relative safety of the warmer months. Respiratory diseases and other acute infections account for the greater part of winter's hazard, but the increased heart load and metabolic breakdown that come with the higher combustion level of winter also provide a considerable portion of the



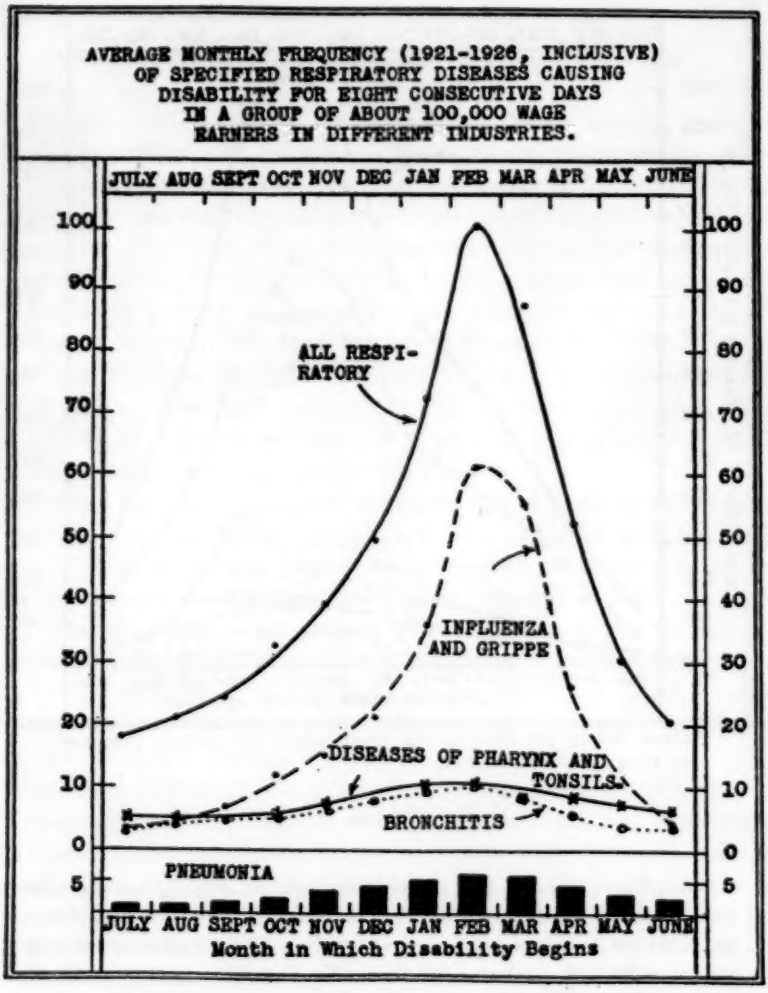
* About twenty per cent of the total number of persons included in this record were women.

FIGURE 1

Note: Figs. 1 and 2, and the sickness data of Fig. 6, are reproduced (with permission) from *U. S. Public Health Report*, No. 1214 (March 16, 1928) on Importance of respiratory diseases as a cause of disability among industrial workers, by Dean K. Brundage, senior statistician. Sickness data of Fig. 6 have been brought up to date in more recent Public Health Reports.

increased ill health. Figures 1 and 2 graphically portray this winter peak of respiratory disease among persons employed in industrial occupations and emphasize the relative safety of summer.

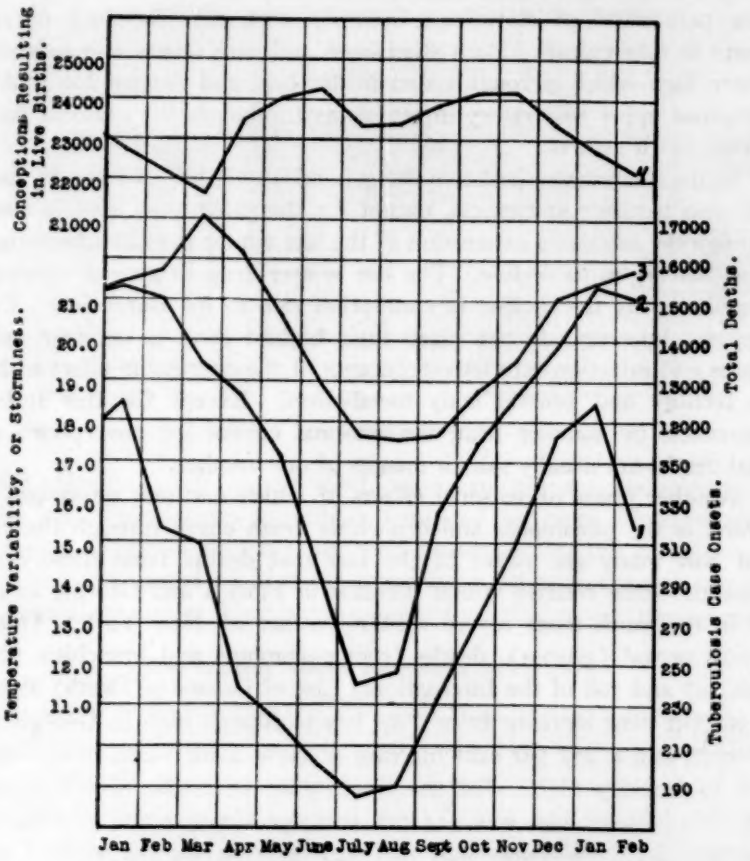
In Figure 3 is presented the similar seasonal curve (Curve 1) for the onset of symptoms in pulmonary tuberculosis at Cincinnati. Curve



*About ten per cent of the total number of persons included in the record were women.

FIGURE 2

Seasonal Variations in Tuberculosis Onsets in Relation to Conceptions, Total Deaths, and Temperature Variability.



1) Tuberculosis onsets are for patients who died at the Hamilton County Tuberculosis Sanatorium from 1909 to 1934.
2) Temperature Variability curve represents mean monthly values for the past 60 years for the eight stations named in text.
3) Curve for Total Deaths represents 5 year average of total deaths, month by month, for same eight cities from 1924 to 1928.
4) Conceptions resulting in live births also represent 5 year average.

FIGURE 3

2 of the same figure indicates the relative storminess of the weather through the seasons (combined data from Cincinnati, St. Louis, Minneapolis, Chicago, Cleveland, Boston, New York and Baltimore) and the close parallelism of storminess intensity with the frequency of case onsets in tuberculosis. Both storminess and case onsets rise to a mid-winter high which is roughly double the July and August low. With the minor upper respiratory infections and influenza the seasonal swing is very much greater.

In the same figure is shown the general way in which the total death rate also parallels storminess, except for the progressive rise in deaths through the metabolic exhaustion of the late winter months when storminess has begun to decline. The late winter drop in general vitality is also shown by the decline in conception rate to its March low. Conceptions, however, do not reach their highest level in summer, when deaths and infections are lowest, because of the depressing effect of heat on fertility and general body metabolism. Except for this fertility depression by summer heat, the seasonal curves for conceptions and total deaths are usually mirror images of one another.

Another phase of seasonal effects of which northern physicians are aware, is the pneumonia and bronchitis death curve through the year. But how many are aware of the fact that deaths from these causes show the same relative winter increase in Florida and Georgia as they do in the much more severe winter weather of New York? Over a 5-year period (1930-4), deaths from pneumonia and bronchitis (Nos. 106, 107 and 108 of the International List of Causes of Death) showed a 308 per cent increase from July low to March high in Georgia and Florida, and a 287 per cent increase in New York State from August low to January high. For the single year 1932, the March increase over the August low was 414 per cent for Georgia and Florida, 465 per cent for New York State and 349 per cent for the whole United States Registration area.

In the southern hemisphere, however, quite a different situation exists. There winter cold is not accompanied by the year's greatest storminess. Greatest storminess in both hemispheres seems to come at the time of year when the earth is nearest the sun (our mid-winter) at which time the temperate zone storm belts shift from each pole down nearer the equator. In July, when the earth is farthest from the sun, the storm belts shift back poleward and leave both temperate zones less stormy. With us in the northern hemisphere, cold and greatest storm-

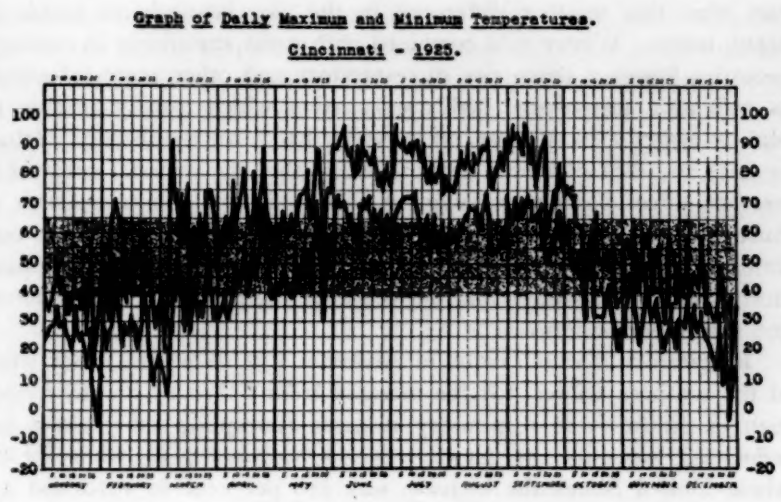


FIGURE 4

iness coincide, while in the south temperate regions the winters are calm and the summer warmth is tempered by more frequent storm changes. These differences are well illustrated by the accompanying graphs (Figs. 4 and 5) of daily temperature behavior through the year at Cincinnati and at Melbourne. Little thought has yet been given to

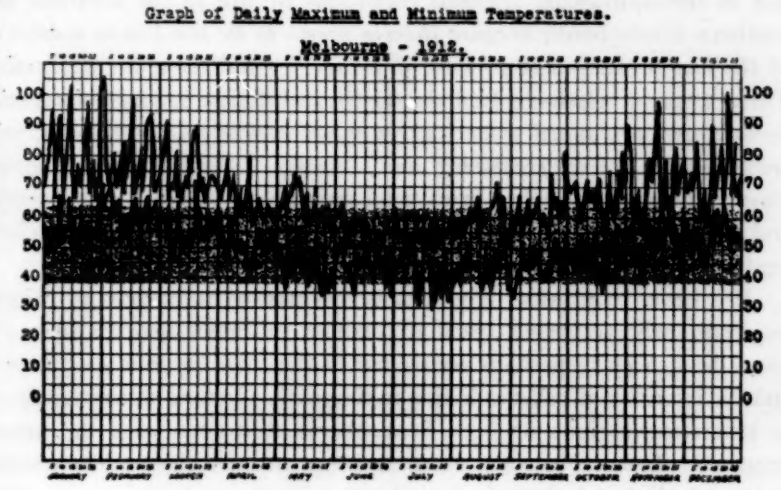


FIGURE 5

just what this weather difference in the two hemispheres means in health terms. Winter cold combined with great storminess in northern countries brings a sharp rise in respiratory and other acute infections, as well as a progressive bodily exhaustion which usually reaches its peak in March. In summer, on the other hand, we are sharply subdued by heat and lack of storm stimulation, so that the seasonal contrast in weather effect becomes very great. In southern countries, such as Australia and Argentina, man lives under more equable weather conditions the year round, with summer warmth tempered by frequent storm change and winter cold not rendered highly dangerous by abrupt and severe fluctuation.

Respiratory disease deaths in Australia (1) show this lesser stress of the southern winter, for the increase from February low to August high in deaths from respiratory diseases (excepting tuberculosis and influenza) was only 151 per cent (years 1907 to 1915), while for the whole United States the increase was 316 per cent in 1910 and 471 per cent in 1915 from August low to March high. Similar comparison of summer and winter differences for tuberculosis deaths shows only 21 per cent for Australia and 42 per cent and 50 per cent for the United States. Evidently, judging by respiratory disease deaths, the winter hazard is over twice as great in the northern than it is in the southern temperate zone.

Detailed attention has been given to the seasonal variation in health, and in the contrasting seasonal conditions of life in the northern and southern hemispheres, *because therein seems to lie the key to a solution of the health changes in periods of prosperity and economic depression. There exists a relatively high degree of correlation between depression periods and prolonged elevations in mean monthly temperatures, with reduction in storm frequency and severity.* Periods of subnormal temperatures, on the other hand, tend strongly to be years of prosperity and rising business activity. This relationship has been carefully studied (2) and seems to be a true finding.

We have, then, after eliminating the marked influences of season, an irregularly recurring cycle of change in mean temperatures and storminess, a cycle perhaps controlled in the main by sun spot activity and the intensity of solar radiation to the earth. Just as storm turbulence in temperate regions of both hemispheres fluctuates with the annual change in distance between earth and sun, so also does earth weather seem to be linked in its principal phases with the major sun-spot cycles.

And as these periods of unusual warmth and calm come over the earth, they induce in man an effect somewhat analogous to that of the summer season. With the lessened climatic drive, his energy and urge to do abate, and he takes life at an easier pace. And with the lessened storminess, respiratory and other acute infectious attacks strike less frequently and the general health markedly improves. Thus it is that we have major business slumps, and the health improvement accompanying

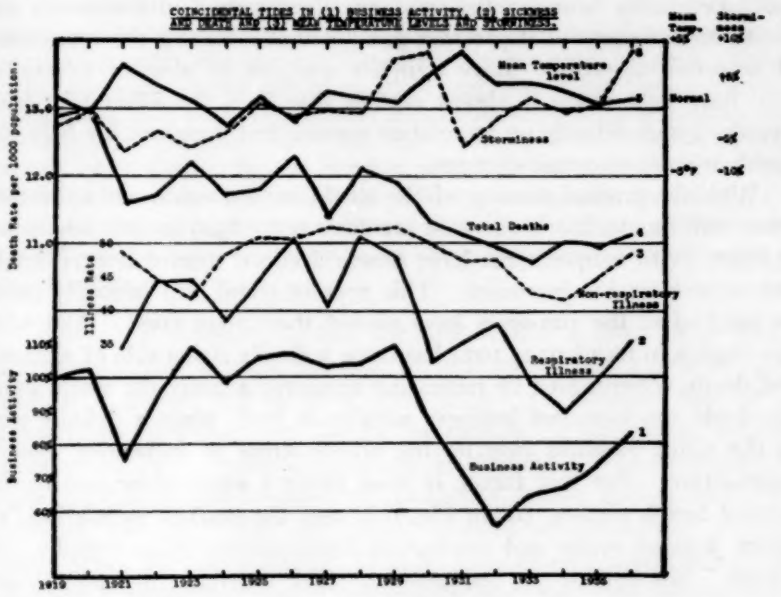


FIGURE 6

them, based on the same extrinsic influence—change in mean temperature and storm turbulence of the earth's atmosphere.

Figure 6 illustrates well the workings of these relationships between depressions, weather and health in recent years. Only at the time of major warm waves over the earth do we find storminess falling well below normal as temperatures rise, as in 1921-2 and the warmth that has coincided so closely with the recent severe depression. The general parallelism between respiratory attacks, causing absence from work in industrial employees, and mean annual storminess is quite as obvious from inspection of these graphs. Total deaths show a somewhat less

striking parallelism, and non-respiratory illness least, but all demonstrate the health improvement that comes in periods of prolonged warmth and calm such as the recent depression years afforded.

Huntington some years ago (3) pointed out this relation between general health and economic activity, but did not at that time relate either to change in weather and its effects directly on man. He rather believed that the health changes themselves were basically responsible for the economic cycles, the wastage of the rising ill health in prosperous years eventually bringing the economic downturn, and conversely the health improvement of depression periods finally causing the restoration of economic up-trend. More complete analyses of weather effects on man have now made it almost certain that it is the effect of major weather cycles directly on population masses that accounts for both the health and the economic changes.

With the gradual passing of the world-wide warmth and calm that came with the decline in sun-spot numbers from 1929 to their low point in 1932, mean temperatures have slowly declined toward normal levels and storminess has increased. This present trend will probably carry on until after the sun-spots have passed their 1939 crest. And with this change in trend since 1932 has come a slowly rising tide of sickness and death, accompanied by increasing economic activity the world over. No doubt the increased business activity in itself plays a definite part in the rising sickness rate by the added stress in increasing energy expenditure. But this factor is most likely a very minor one in the general health picture, for in Fig. 6 is seen the marked parallelism between weather cycles and respiratory illness *among those actually employed*. No figures are available to show whether the unemployed enjoyed a greater or lesser change in general health than did those actively at work.

Various ramifications of this relationship between weather, health, and economic state come to light from time to time. Just recently an article appeared in the *Statistical Bulletin of the Metropolitan Life Insurance Company* (4), pointing out a *relative* increase in the tuberculosis death rate since 1934. No actual country wide increase has yet occurred, but the long decline in tuberculosis deaths has received a sudden check, with the possibility that a true increase will be recorded in 1937. Thus among 17,500,000 industrial policy holders, the tuberculosis death rate dropped 8.2 percent from 1933 to 1934, 6.1 percent from 1934 to 1935, only 2.9 percent from 1935 to 1936, and during

the year 1936 there has been practically no further decline! Quoting further from this interesting article:

> The depression years have been perhaps the most remarkable period in the history of the campaign against tuberculosis in the United States. As was inevitable, the people, as a whole, were faced during these years with more worries and perplexities than ever before. There were the problems of insufficient or improper food; millions of people lived in congested quarters and endured other hardships. Environmental conditions in general were such as would be expected to cause an increase rather than a decline in deaths from tuberculosis. Instead, the mortality rate not only continued to fall during these years of economic maladjustment but it actually fell at a faster rate than during the predepression years. Now, with economic conditions definitely improved, it appears that the decline has either ceased altogether, or, at best, that it has become negligible. The question, then, arises as to whether the current status of the tuberculosis death rate is an aftermath of the depression. Has there been an impairment in American vitality, which did not become manifest until the depression itself had lifted? Public health workers have feared that this very contingency might arise. It is certain that the unfavorable tuberculosis situation which now confronts the country has not been due to any abatement in the efforts toward tuberculosis control; for there has been no let-down.

While it is discouraging that the long decline in tuberculosis should have shown this check in the face of well maintained anti-tuberculosis activity, it should not be at all surprising. In previous decades the tuberculosis mortality was falling so rapidly as completely to overshadow the lesser cyclic fluctuations in sickness. Now, however, the curve of decline has flattened out to such a degree, and at such a low level of mortality, that the minor changes accompanying economic cycles stand out more clearly. Falling temperature levels since 1932, with the irregular increase in storminess, have caused a general rise in sickness and death rates. It is to be expected that respiratory ailments should predominate in such a rise, so why should we not anticipate a relative increase in tuberculosis? In Canada, the year 1935 witnessed an actual increase in the crude pulmonary tuberculosis death rate from 48.9 per 100,000 population to 50.1.

Students of medical economics have been inclined to account for the marked decline in calls for professional service during depression years on purely financial grounds. This decline may, in fact, be partly due to the patient's disinclination to thus burden his more slender purse. But there should no longer be any doubt that an important factor is also the real decline in illness. Were the financial factor paramount,

there would be no decline in death rate along with fewer sickness calls, but instead the rate would be likely to show a sharp rise.

This *cyclic* tide in sickness and death, dependent on coincidental fluctuations in weather factors and economic activity, is a real and important biologic manifestation of response to environment and stress. It is on the same basis as the seasonal tide in health and energy. Its implications should be kept clearly in mind in any disease investigation that involves a time factor. Findings on diabetic patients obtained in summer cannot logically be compared with those of late winter, nor can those on Toronto or Boston diabetics be compared with findings on diabetic patients of sub-tropical or tropical regions. Frequency and severity of pneumonia also show striking variations from season to season and year to year. And so we might go on indefinitely naming diseased states in the evaluation of which the time factor is of great importance.

One naturally wonders where the tendency for sickness and death rates to change with world temperature levels would lead us in the longer-time temperature changes that take place through the centuries. Steadily improving health has certainly been the general trend with the rising temperature levels of the past half-century or more, but how much of this was due directly to temperature changes? Many will rather attribute it entirely to improved therapeutic, hygienic, and dietary standards. Basic changes in knowledge available, and in the ability to transform that knowledge into effective action, make it impossible to evaluate the factor of environmental change over long periods of time. Standards do not change, however, during the shorter, irregularly-timed fluctuations, nor during the seasonal cycle, so that from them logical conclusions can safely be drawn.

In view of the relationships here set forth, it would seem that the medical profession, and others, may well cease marvelling at the good health of depression periods, and cease prophesying dire results in future years from the lowered standards of living during hard times. Death rates do rise after depressions, but apparently not as an after-effect of depression influences. Extra-terrestrial forces, working mainly through their influence over world-weather, produce these marked tides in human health and energy; and it is the effect of these outside cyclic forces that so affects the work of the medical profession through the decades.

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THE VARIABILITY OF NITROGEN EXCRETION IN TWENTY-FOUR HOUR PERIODS AS COMPARED WITH THAT IN LONGER PERIODS[1]

BY L. W. SONTAG AND MARTHA POTGIETER

The Samuel S. Fels Research Institute
Antioch College, Yellow Springs, Ohio

IN preceding studies by Pyle and Huff ('36) and Huff and Pyle ('37) it was shown that 3-day periods of observation with 24-hour sampling on the third day could be used as a method for determining average trends of calcium and phosphorous metabolism of women during pregnancy. The limitations of intermittent sampling and of short balance periods are apparent, and the problem of applying the method to other metabolites was approached with some hesitation. Further investigation of the use of this technique seemed pertinent, however, since one of the perplexing problems in human nutrition is sampling, and it is obvious that one needs as short a balance period as possible if he is studying metabolism during pregnancy where the rates of change in both the fetal and maternal organism are not constant.

It has seemed to us that there are two methods of treating data which might be expected to yield information as to the efficacy and validity of this sampling technique for the study of nitrogen metabolism, particularly during pregnancy. The first of these methods is the comparison of urinary nitrogen excretion on the third day of the metabolism run with that on the first and second days. Such a procedure necessitates, of course, a quantitatively and qualitatively constant diet during all 3 days of the period. Because of the nitrogen lag factor, we should not expect urinary nitrogen from each of these 3 days to maintain a

[1] The authors wish to acknowledge the work of Dr. Walter Seegers and Miss Idell Pyle in collecting a part of the data for this paper and for their assistance in working it up.

constant level even though the 3-day test period was accurate. If, however, the urinary nitrogen of the second day of the period was not appreciably different from that of the third, despite the nitrogen lag, we would have significant evidence as to the validity of the 3-day test period, in which only the nitrogen excretion of the third day was quantitatively determined.

The second method is the comparison of the variability of the nitrogen figures as obtained from the third day of the 3 days of constant diet, with those of other observers, which were obtained from pooled samples of longer periods. In this instance variability in nitrogen figures, if it were greater in the figures obtained from the 24-hour collections than in figures obtained from longer pooled periods, would indicate inaccuracy of the short time sampling period, while a variability which was not greater than that obtained from 4- or 5-day pooled samples would tend to confirm the validity of the 24-hour collection period with the 48-hour preparatory period for sampling nitrogen metabolism. For this comparison we have selected the reports of Macy *et al.* ('30) and Coons *et al.* ('30 and '34) of their nitrogen metabolism studies.

METHODS USED FOR COLLECTING AND COMPARING URINE NITROGEN DATA

The subjects used for a comparison of the urinary nitrogen excretion of the first, second and third day of a 3-day test period in which the diet was maintained qualitatively and quantitatively the same, were not the same group as that used for a comparison of variability with Macy's and Coons' groups. Six of these test runs were done on one pregnant subject (Seegers, '37, in press), 3 on another pregnant subject, 1 each on two pregnant subjects, and 1 each was done on four non-pregnant women, making a total of 15 test periods. The diet was selected for them, care being taken not to include any food which any of the group disliked. In order to determine within what limits of nitrogen content the diet could be reproduced, seven sample analyses of it were done. The maximum error of reproduction in these diets was 2.4 per cent. The average error was 1.1 per cent. The nitrogen determinations were made by the Macro-Kjeldahl method. Urinary nitrogen was determined on 24-hour samples collected under toluene.

COMPARISON OF FIRST, SECOND AND THIRD DAY URINARY NITROGEN EXCRETION

The results of this comparison are presented in Table 1. Urinary nitrogen of the first day differs from that of the second day by as much as 87.4 per cent in one instance while the mean per cent deviation of the first day determinations is 13.5 per cent. When the second day nitrogens are compared with those of the third day, we find that the

TABLE 1

PATIENT	GRAMS NITROGEN IN URINE				PERCENT DIFFERENCE BETWEEN DAYS AND BETWEEN 3RD DAY AND AVERAGE		
	1st Day	2nd Day	3rd Day	Average	Between 2nd & 1st	Between 3rd & 2nd	Between av. & 3rd
C.B.	9.222	9.184	9.119	9.175	+ 0.4	+ 0.7	— 0.6
	9.363	8.443	8.625	8.812	+10.9	— 2.1	— 2.1
	9.035	8.753	9.239	9.009	+ 3.2	— 5.2	+ 2.5
	8.603	7.871	9.048	8.507	+ 9.3	—13.0	+ 6.3
	8.039	7.936	7.543	7.839	+ 1.3	+ 5.2	— 3.8
	4.928	6.641	6.913	6.161	—21.5	— 3.9	+12.2
B.S.	4.628	7.489	7.389	6.502	—38.2	+ 1.3	+13.6
M.C.	9.296	4.960	6.920	7.059	+87.4	—28.3	— 1.9
M.S.	6.728	6.478	7.356	6.854	+ 3.8	—11.9	+ 7.3
B.M.	6.986	6.801	6.811	6.866	+ 2.7	— 0.1	— 0.8
L.P.	11.401	10.164	10.948	10.838	+12.2	— 7.2	+ 1.0
	13.388	12.819	12.121	12.776	+ 4.4	+ 5.7	— 5.1
	12.328	12.934	12.479	12.580	— 4.8	+ 3.7	— 0.8
E.P.	12.449	12.638	12.292	12.460	— 1.5	+ 2.8	— 1.3
M.C.	10.050	10.200	10.200	10.150	— 1.5	0.0	+ 0.5
					13.5*	6.1*	4.0*

* Mean percentages disregarding signs.

greatest difference in any one subject has dropped to 28.3 per cent while the mean per cent of deviation has dropped to 6.1 per cent. When we compare the results of the third day (which represents the period of sampling in the 3-day test) with the mean nitrogen excretion for the 3 days we find greatest deviation in any instance has dropped to 13.6 per cent, while the mean per cent of difference between the results

obtained from pooled samplings of the full 3-day collection period and the results obtained from the third day only has dropped to 4.0 per cent.

The method of collecting the data which we have compared with Macy's and Coons' data has been described in detail elsewhere (Pyle and Huff '36). Briefly, the subjects were put on a 3-day test period approximately every 28 days during pregnancy, and were shown how to prepare and weigh food in their own homes. Each subject selected

TABLE 2

SUBJECT	NITROGEN BALANCES, TWENTY-FOUR-HOUR COLLECTION PERIODS					
	Days pre-delivery	Food	Feces (*grams per day*)	Urine	Balances used in matched comparisons *Pos.*	*Neg.*
III$_b$	226	5.72	1.25	8.19		—
	198	12.33	1.05	13.98		—
	170	13.21	1.77	13.44		—
	142	13.01	1.78	13.06		—
	116	11.58	2.11	11.17		—
	86	9.49	1.44	10.00		—
	51	12.82	1.07	8.94	+	
	10	10.07	1.30	9.47		—
VI	161	7.95	1.80	9.24		—
	133	10.57	1.50	10.64		—
	98	9.30	1.07	11.57		—
	77	16.09	0.97	9.89		—
	49	8.88	1.26	10.04		—
	21	9.89	0.84	8.61	+	
VII	75	12.84	1.50	10.55	+	
	47	14.68	1.63	9.58	+	
	6	12.61	1.47	8.17		
VIII	85	11.24	0.68	8.01	+	
	57	10.47	1.26	7.57	+	
	29	9.29	1.64	7.19	+	
	4	7.14	1.56	7.34		—
X	238	15.24	3.38	11.47	+	
	210	16.93	3.29	12.04	+	
	182	15.27	1.44	11.99	+	
	155	10.88	2.10	10.83		—
	126	11.76	2.52	9.83		
	98	13.44	1.81	11.07	+	
	69	9.53	2.98	9.27		—

TABLE 2 (*Continued*)

SUBJECT	NITROGEN BALANCES, TWENTY-FOUR-HOUR COLLECTION PERIODS					
	Days pre-delivery	Food	Feces (*grams per day*)	Urine	Balances used in matched comparisons	
					Pos.	*Neg.*
	42	10.66	2.14	10.53		—
XI*	7	13.18	1.51	12.45		
	6	13.82	1.11	12.64		
	5	14.65	1.17	12.29	+	
IX**	14	13.82	...	11.72		
	13	8.49	4.34	8.12		
	12	8.83	0.93	7.74		
	11	16.69	...	9.48		
	10	10.54	2.66	7.64		
	9	18.21	1.39	9.86		
	8	13.49	5.86	8.41		
XII	42	15.51	...	11.40		
	41	16.32	...	10.16		
	40	15.53	...	10.95		
	24	16.25	...	13.39		
	23	16.30	...	12.82		
	22	15.45	...	12.12		
	10	13.66	...	12.33		
	9	15.99	...	12.93		
	8	15.02	...	12.48		

* Determinations for each of the 3 days, same kind and quantity ingested each day, except for water ingestion.

** Subject IX was on self-chosen diet which was different for each day. Feces were analyzed stool by stool. The beginning and end of the week's period were marked off with carbon and carmine, respectively. The figure for fecal nitrogen in each stool is tabulated opposite the date on which it was excreted. The food and urinary nitrogens represent 24-hour samplings.

her own diet for the 3 days and was asked to make it representative of her customary choice of food. During each day of the test period the subject ate as nearly as possible the same kind and the same amounts of food. The same kind of meal was used during subsequent test periods with occasional substitutions in certain food items, such as fresh fruit in season. The quantity of each food item eaten varied during the course of pregnancy, but complete omissions were not permitted in the

consecutive test periods after the individual's choice of her "test meals" was made. Collections of food aliquots, and of feces and urine were made for the last 24 hours of the 3-day period. The feces was marked off with carbon and carmine markers. Urine nitrogen collections were made and analyses done as already described. The food samples had been dried on copper coils heated by steam at a temperature slightly above room temperature after ethyl alcohol had been mixed into the ground wet sample. Concentrated H_2SO_4 was added to the feces when they were collected and nitrogen was determined from this wet digest. Balance figures are contained in Table 2.

Many of the nitrogen balances from this latter group proved to be negative. Our subjects were often in negative calcium and phosphorus balance as well. It was found previously (Huff and Pyle '37) that subjects in negative balance tend to excrete calcium or phosphorus in a different manner than subjects in positive balance. These differences were most apparent when the quantity of a metabolite found in its main channel of excretion was studied. Hence the nitrogen balances were assembled as negative or positive in order.

The general characteristics of the Fels subjects and their infants have been described in preceding papers (Pyle and Huff '36), (Huff and Pyle '37), and (Seegers '37, in press). Three of the four used in the positive balance comparison were the same as were used in the calcium and phosphorus comparisons (Pyle and Huff '36) (Huff and Pyle '37). Subject X was substituted for Subject IV because fecal nitrogen determinations for the latter were available only on dried samples, and determinations made on dried fecal material are not comparable to those made on wet samples because of losses incurred during the drying process.

The comparison was made in the following way. First, 12 Fels positive balances were compared alternately with 12 given by Macy and her co-workers ('30), and then 12 from those given by Coons and her co-workers ('30). The basis for matching was stage in pregnancy and care was taken to make matchings correspond within a week.

All of our inferences were drawn from critical ratios computed for means and standard deviations, and from them significance of differences found were interpreted by using the criteria given in the *Handbook of Chemistry and Physics,* volume 20, page 204. A difference was called *significant* if the critical ratio was 3.0 or greater; *somewhat or tending toward* significant if it was 2.0 to 3.0; and *insignificant* if it was less than 2.0.

TABLE 3

Comparison of means, standard deviations and critical ratios of positive nitrogen balances

	STUDY			CRITICAL RATIOS		
	Macy	Coons (*grams per day*)	Fels	Macy and Coons	Macy and Fels	Coons and Fels
Food						
Mean.....	18.20±0.62	10.96±0.38	13.06±0.75	10.01 (M)*	6.91 (M)	3.20 (F)
Standard deviation	3.17±0.44	1.94±0.27	3.83±0.53	4.36 (M)	1.43 (F)	3.14 (F)
Feces						
Mean.....	1.87±0.07	1.84±0.06	1.66±0.16	0.32 (M)	1.07 (M)	0.92 (C)
Standard deviation	0.36±0.05	0.32±0.04	0.83±0.12	0.72 (M)	3.75 (F)	4.21 (F)
Urine						
Mean.....	13.94±0.42	6.96±0.20	9.94±0.34	15.08 (M)	7.42 (M)	7.46 (F)
Standard deviation	2.15±0.30	1.02±0.14	1.77±0.24	3.46 (M)	1.01 (M)	2.67 (F)
Fecal Ratio**						
Mean.....	0.105±.005	0.173±.008	0.125±.010	7.21 (C)	2.07 (F)	3.16 (C)
Standard deviation	0.024±.003	0.040±.006	0.051±.007	2.41 (C)	4.07 (F)	1.63 (F)
Urinary ratio**						
Mean.....	0.773±.014	0.647±.020	0.764±.020	5.16 (M)	0.20 (M)	3.07 (F)
Standard deviation	0.074±.010	0.102±.014	0.103±.014	1.63 (C)	0.92 (F)	0.68 (F)

* In this table the letter in parentheses indicates which study had the higher value. For example, 10.01 (M) indicates that Macy's group had the higher value in addition to being a significantly different value than Coons' group.

** Ratio means excretion divided by ingestion. The figure represents the same computation which is designated as "partition" in the calcium and phosphorus study made for these subjects. The substitution was made to avoid the specialized use of partition in respect to nitrogen metabolism. It should not be confused with the term critical ratio used in the title for the table and described in the text.

THE MACY-FELS-COONS TOTAL NITROGEN COMPARISON

Positive balance matchings, the 12 from each study, revealed the following points about differences judged by the critical ratios (Table 3).

Nitrogen Ingestion. The three groups differed significantly in quantity of nitrogen ingested. Macy's group had the highest average level, Fels subjects the intermediate quantity, and those of Coons the lowest level of ingestion. The differences were significant throughout. The Coons group had less variability in quantity ingested than either of the other two groups.

Fecal Nitrogen. The difference in average output for the three groups was insignificant. The amount excreted by the Fels subjects was significantly more variable, exceeding Macy's group in variability, although the average ingestion was less.

Urinary Nitrogen. The three groups differ widely and significantly in average daily urinary nitrogen excretion. The daily nitrogen excretion in the 24-hour collection periods (Fels) was not more variable than it was in either of the other two groups where the collection period was 4 to 6 days.

The variability in average daily urinary nitrogen excretion was less in the Fels group than it was in the Coons and Macy groups. When the ingestion was high, the excretion through this channel was high.

SUMMARY

The urinary nitrogen output on a constant diet for each of 3 consecutive days during 10 test periods on eight subjects was compared. The output for the first day was compared with that for the second day, the second day with that for the third day and the 3-day average with the output for the third day. The results show that the greatest difference between the third-day figures and the 3-day average in any test period was 13.6 per cent and that the mean of the per cent difference between the third-day figures and the 3-day averages, disregarding sign, was 4.0 per cent.

We have also compared figures of the fecal and urinary nitrogen of 12 positive balances on Fels subjects obtained from test periods where the 3-day diet was qualitatively the same but in which only the third day was used as a balance period, with those of 12 each of Macy's and of Coons' longer balance periods by means of the critical ratio technique.

partition in respect to nitrogen metabolism. It should not be confused with the term critical ratio used in the title for the table and described in the text.

Fecal excretion of the Fels group was slightly more variable than that of the other two groups. Urinary nitrogen was not more variable in the Fels group than in Macy's and Coons' groups.

CONCLUSIONS

We believe that the data presented in this paper indicate that the 3-day test period, using the last day as a balance period as described, is sufficiently reliable to justify its use for measuring nitrogen metabolic trends during pregnancy. It is possible that a longer preliminary period of qualitatively constant diet might be essential for patients who had been taking very abnormally high or low protein diets for some time previous to testing.

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THE RELATIONSHIP BETWEEN HEIGHT AND WEIGHT OF MALE AND FEMALE INFANTS BETWEEN THE AGES OF TWO WEEKS AND ONE YEAR

BY T. E. RAIFORD, PH. D.

The Research Laboratory of the Children's Fund of Michigan, and the Department of Mathematics, University of Michigan, Ann Arbor, Michigan

ALTHOUGH height and weight are among the most common, as well as the most easily made physical measurements, they continue to be basic indicators of normal physical development. The fact that papers and statistical expositions continue to appear on this subject is due to the wide range of methods in statistical presentation, the varying geographical locations from which the data are gathered, the differing racial stocks included in different studies, the widely varying age ranges covered, and other factors affecting the homogeneity of the groups studied. Such variety makes it possible for each presentation to offer a real contribution to vital facts about growth and development.

An extensive review of the literature in this field is unnecessary. Many good bibliographies are available. Bayley and Davis (1) presented a particularly good one. One of the most complete and elaborate presentations treating only these two measures is the hundred-and-fourteen page report prepared in 1921 on *Statures and Weights of Children Under Six Years of Age* (2) under the supervision of R. M. Woodbury. This report presents, in addition to height and weight measurements from local studies made in Iowa, New York City, and California, measurements from 172,000 children throughout the United States. The averages from such a large group would seem to possess great reliability and consequently have often been used to make "standard curves" for comparison. Even with so great a number, however, one of the first things noted is that the average weight for the white females at birth exceeds by more than half a pound that of the white males. This interesting statement is not, however, born out by the data from

Iowa, New York City, and California, and its finality is not impressive when it is noted that there are only sixty-two white males and fifty-six white females furnishing these averages at birth.

In a previous report (3) a comparative graphical analysis of the heights and weights of 472 nude children was made from data taken at the Research Laboratory of the Children's Fund of Michigan* using, among others, Woodbury's composite (males plus females) averages as the basis for comparison. This report, and the interest created by the papers mentioned above, made it desirable to present some results from the data of the males and females taken separately. In addition to presenting these averages, from which one may readily sketch the age-height and age-weight curves of nude subjects for purposes of graphical comparison, we present some algebraic relations suggested by such graphs and point out some of the advantages as well as some of the difficulties, both in their derivation and in their use.

It should be pointed out in the beginning that capable students in this field of study would differ widely upon what comparisons could properly be made between these and other published results, since two groups chosen at random for study are rarely mutually homogeneous. There are two points to be stressed: first, that the data of this study are measurements of children in the age range of two weeks to one year, and second, that racially the children are the conglomerate representing the industrial population of the city of Detroit.

Table 1 gives the averages for the groups and successive age intervals as indicated.

These averages coordinated with age and pictured graphically suggest a functional relationship of the form $x = k_0 + k_1 y + k_2 y^2$. The statement that some other relationship,—algebraic, exponential, or logarithmic,—is better suited to the data in question can only be answered by the comparison of some measure of Goodness of Fit for whatever form is used and by finding if, from the particular form chosen, we can answer the questions which we should like answered from the data. It must be kept clearly in mind that whatever form is chosen correctly relates only the average heights (or weights) to age. To make the general statement that the relation between height and age can be represented by the form $a = b_0 + b_1 h + b_2 h^2$, where a and h denote age

* The material presented in this paper was obtained during a two-year series of studies upon the growth and development of infants (4) by the Research Laboratory of the Children's Fund of Michigan.

TABLE 1

AGE RANGE IN DAYS	14-42	42-70	70-98	98-126	126-154	154-182	182-210	210-238	238-266	266-294	294-322	322-350	350-378	378-406
No. of measurements.....	144	223	240	233	217	223	195	186	163	175	156	137	136	17
Mean heights of males (in centimeters)	54.48	57.49	60.30	62.88	65.32	67.04	68.56	70.19	71.30	72.85	74.23	75.41	76.62	77.16
No. of measurements.....	108	203	186	180	174	171	152	144	118	136	129	106	91	17
Mean heights of females (in centimeters)	53.48	56.10	58.84	61.29	63.32	65.14	66.78	68.42	69.75	71.13	72.26	73.43	75.02	75.03
No. of measurements.....	163	281	251	225	224	228	189	189	162	170	159	134	134	16
Mean weights of males (in pounds)	8.68	10.45	12.13	13.87	15.34	16.73	17.80	18.87	19.68	20.64	21.24	21.99	22.62	22.57
No. of measurements.....	123	232	208	183	180	171	153	144	118	135	125	109	90	15
Mean weights of females (in pounds)	8.33	9.71	11.31	12.86	14.19	15.46	16.56	17.17	18.37	18.93	19.84	20.25	20.82	21.66

and height respectively, and undertake to determine the constants for this equation from the original data, by the usual method of least squares, presents a tremendous problem in computation. Also, the equation thus determined would probably be slightly different from the one determined by the fourteen averages alone. The latter, however, corresponds more closely to the graphical comparison so often used and is the one which we shall present.

Statements regarding the technique used and assumptions made in arriving at such equations are necessary. Denoting age and height by the letters a and h respectively, a law of relationship of the form $a = b_0 + b_1h + b_2h^2$ is more or less obvious for the period covered in this study. Establishing an equation of this form by the method of least squares, however, makes the errors of prediction in age from height a minimum; whereas, we should like to have the errors in height as predicted from age a minimum. This, from the nature of the relationship, presents obvious difficulties. However, as we shall see, the errors of prediction of height from age by the equation we have suggested proves exceedingly small, since each of the four cases presented results in probable errors of prediction which are quite insignificant according to Fisher's χ^2 test (5) for Goodness of Fit, and consequently, the method seems amply justified. Therefore, the equations have been determined from this form and subsequently solved for h (or for w in the case of weights), since for use as a clinical tool one would like to know—given the age—what is the corresponding average height (or weight). From this form, with the aid of a calculating machine, such calculations can be made very readily.

Recording the constants to as many decimal places as shown below is justified only on the assumption that the averages are exact figures. Assuming that the averages from the original data are exact figures, the best fitting parabola (or other curve) is justifiable.

The equations determined by the given averages may now be stated, their meaning and use having been clearly defined.

$$(1)\quad h_m = 48.391986 + 31.675641 \cdot \sqrt{.002255\,a - .036960}$$

$$(2)\quad h_f = 56.108220 + 31.961135 \cdot \sqrt{.002235\,a - .020535}$$

$$(3)\quad w_m = 4.507477 + 12.328357 \cdot \sqrt{.005359\,a - .069585}$$

$$(4)\quad w_f = 4.464810 + 11.114075 \cdot \sqrt{.006427\,a - .113564}$$

The average errors of prediction from these equations are found to be .26 and .23 inches respectively for the height averages, and .27 and .23 pounds respectively for the weight averages. Applying Fisher's χ^2 test for Goodness of Fit the probability factor P in each case is well above .95 and although other satisfactory relationships might be found, such a large value for P makes these highly satisfactory. If, for any reason, it seemed preferable to express weight in terms of grams, that is, by placing $G = 453.6w$ in (3) and (4), the errors would be relatively greater but would not effect in any way the numerical measure of Goodness of Fit for the law we have assumed.

Now that laws of relationship between the variable quantities have been established the rate of change of one with respect to the other is readily determined, and as readily, how this rate is behaving at any given age. These again are not characterized by very simple expressions. The law we have assumed, if solved for y, may be written $y = c_0 + c_1\sqrt{c_2 x - c_3}$, where x denotes age and y denotes either height or weight. If now we denote by y' the rate at which y changes with age and by y'' the rate at which y' itself changes with age, we then have

$$y' = \frac{c_1 c_2}{2\sqrt{c_2 x - c_3}} \qquad y'' = \frac{-c_1 c_2^2}{4\sqrt{(c_2 x - c_3)^3}}.$$

From these expressions it is evident, since c_1 and c_2 are both positive numbers, that while y' steadily decreases y'' steadily increases throughout the complete age interval; that is to say, that although both height and weight increase with age, y' being positive, this increase takes place at a decreasing rate of speed. This latter statement is evidenced by the fact that as x increases the denominator of y' increases and also by the fact that y'' is negative.

The statements of the preceding paragraphs are illustrated by the tabulated values for the four cases under consideration as given in Table 2.

Remembering that the unit of time in the problem is one day and the unit of weight say, is one pound, reading from the fourth line of the table we see that male weights (average) are changing at the rate of .13 pounds per day, at the age of 28 days, whereas the rate itself is decreasing at the rate of .0042 pounds per day. From age 28 to 360 days the change in this rate of growth has increased from —.0042 to —.000038. Similar statements can be made for the other cases under consideration.

TABLE 2

(1)	(2)	(3)	(4)	y'	(5)	(6)	y''	(7)
x,y	y'	y''	For a=28		For a=360	For a=28		For a=36
a, h_m	$\frac{.035714}{\sqrt{.002255\,a - .036960}}$	$\frac{.000040}{\sqrt{(.002255\,a - .036960)^3}}$	.22		.040	—.0094		—.00059
a, h_f	$\frac{.035717}{\sqrt{.002235\,a - .020535}}$	$\frac{.000040}{\sqrt{(.002235\,a - .020535)^3}}$	.17		.040	—.0046		—.00028
a, w_m	$\frac{.035713}{\sqrt{.005359\,a - .069585}}$	$\frac{.000096}{\sqrt{(.005359\,a - .069585)^3}}$	.13		.026	—.0042		—.00028
a, w_f	$\frac{.035715}{\sqrt{.006427\,a - .113564}}$	$\frac{.000115}{\sqrt{(.006427\,a - .113564)^3}}$	.14		.024	—.0067		—.00035

In order to rank any individual measurement with other measurements at the same age it would of course be necessary to know the values of the standard deviation and measure of skewness for the height and weight distributions at that given age.

The numerical computations in this presentation are a bit cumbersome but in order to answer the questions presented this seems unavoidable. This fact makes it seem worth while to present briefly a method more easily applied in answering certain types of questions when the above rôles of x and y are interchanged and where it is possible to use the simpler form of the equation, namely, $x = k_0 + k_1\,y + k_2 y^2$.

The general questions of rates of change similar to those of the previous discussion involve the use of much simpler forms, namely, $x' = k_1 + k_2 y$ and $x'' = 2\,k_2$. The interpretation of these simple forms is easily made and will not be given detailed discussion. If, however, we wish to determine successive values of x beginning with any given value of y, as for instance, to determine the ages at which the average weights of females are 10 pounds, 11 pounds, 12 pounds, etc., it is easily done by a method of differences.

If the difference between two successive values of x, $x_{n+1} - x_n$ say, be denoted by $\Delta\,x_n$; and similarly the corresponding difference between

two successive values of Δx be denoted by $\Delta^2 x_n$, then general expressions for these respective differences for the law assumed are readily shown to be

$$\Delta x_n = (k_1 + k_2) + 2 k_2 y_n \quad \text{and} \quad \Delta^2 x_n = 2 k_2.$$

Consider the equation relating white female average weights and age which may be written

$$a = 42.780088 - 11.248073 w + 1.259636 w^2.$$

For this equation $\Delta^2 a = 2.519272$, and corresponding to a weight of 12 pounds we have $\Delta a = 20.242827$ and $a = 89.190796$. From these values Table 3 is rapidly constructed.

TABLE 3

w	$\Delta^2 a$	Δa	a
8	2.519272	10.165739	33.412208
9	2.519272	12.685011	43.577947
10	2.519272	15.204283	56.262958
11	2.519272	17.723555	71.467241
12	*2.519272*	*20.242827*	*89.190796*
13	2.519272	22.762099	109.433623
14	2.519272	25.281371	132.195722
15	2.519272	27.800643	157.477093
16	2.519272	30.319915	185.277736
17	2.519272	32.839187	215.597651
18	2.519272	35.358459	248.436838
19	2.519272	37.877731	283.795297
20	2.519272	40.397003	321.673028
21	2.519272	42.916275	362.070031

The three values computed directly by formula are in italics in the table. The remaining values of Δa are built up directly from these values; those corresponding to values of w above 12, by adding successively $\Delta^2 x = 2.519272$, since $\Delta x_{n+1} = x_n + \Delta^2 x_n$, and similarly by successively subtracting $\Delta^2 x$ for the entries below $w = 12$. The remaining values of a are gotten by adding to the computed value 89.190796 the corresponding Δa to obtain the next value of a and repeating this process until the higher values of a are completed. Values of a corresponding to lower values of w are gotten similarly, since $x_n = x_{n+1} - \Delta x_n$. These

values are seen from inspection to correspond closely to the ages estimated at the corresponding successive integral weights of the original averages.

From the data and discussion presented in this paper it is possible to make the following statements applicable to the age range of two weeks to one year of age of children in the industrial area of Detroit:

1. Both height and weight averages follow very closely a law of the form $x = k_0 + k_1 y + k_2 y^2$ where x denotes age and y denotes either height or weight.

2. By means of the errors of prediction from the equations thus determined proper comparisons of these averages with other corresponding averages may be made.

3. Numerical measures for the rate of change of either height or weight with respect to age, and vice versa, are readily obtained for any age within the age range. The behavior of this rate is itself also specifically defined.

4. By a method of differences, a table of ages corresponding to unit changes in height or weight is easily calculated.

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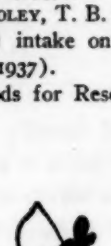

SPOUSAL ESTIMATION OF EMOTIONALTITY

BY RAYMOND ROYCE WILLOUGHBY

Brown University

A FORTY-ITEM personality inventory of the Woodworth-Thurstone-Bernreuter type (modified to permit response in five categories, 0—4, instead of two) was administered by individual interview during 1934 to a population of not quite 1400 persons systematically varied as to age, sex, and conjugal condition. The interviews took place for the most part in the homes of the subjects; care was taken to preserve rapport, and the questions were read to the subject at short intervals (about 5 seconds) in order to minimize rational reflection; the subject recorded his answers on a numbered blank. The present paper is devoted to the evaluation of the results obtained by requesting each member of the 271 married couples involved to record for each item the response he felt his spouse should have made; these estimates were recorded independently, and precautions were also taken to prevent them from being directly influenced by the subject's own response to the same items.

High scores, by the convention used, represent greater emotionality (or neuroticism, or maladjustment) in the conventional sense. The highest possible score is $4 \times 40 = 160$, and the lowest 0. The variable to be most frequently under discussion here has been called the estimate error; it is defined as the estimate minus the response estimated, is assigned to the estimator, and is differentiated as to total and item estimate error. Thus, in an actual case the husband's total score (sum of item scores) was 83, his estimate of his wife's total score (i.e. the sum of his item estimates) 86, the wife's total score 66, and the wife's estimate of her husband's total score (in the same sense) 57; the husband's "total estimate error" is therefore 20 (i.e. 86—66) and the wife's —26 (i.e. 57—83). A positive estimate error thus means that the estimator estimated too high, a negative one that he estimated too low (with the obvious definition that "too high" and "too low" are only brief expressions for "higher than the actual score" and "lower than the actual score").

A question of immediate interest is that of the accuracy with which each spouse predicts the other's total score. This may be evaluated in several ways; for example, the frequency distributions of estimate errors are as follows:

	Below −49	−49– −40	−39– −30	−29– −20	−19– −10	−9– 0	1– 10	11– 20	21– 30	31– 40	*Above* 40
Husbands	4	6	16	23	58	48	57	23	24	8	3
Wives	6	9	14	29	40	65	58	23	10	11	6

The husbands range from the —70 class to the +50 class, about 130 points; the wives from the —60 class to the +80 class, about 150 points. These are to be compared with a total possible range in estimated score of 160 points, and a total possible estimate error of twice that figure. The mean for the husbands is about —3.7 and that for the wives —4.3; the small size of these values may be visualized from the consideration that they would result in an individual case if a spouse should estimate one item response as 0 when it was really 4 and get the other 39 exactly right. The standard deviations are 20.4 for the husbands and 21.2 for the wives; these are very close to the standard deviations for the total scores estimated (18.1 and 20.4 respectively).

The problem of accuracy of estimate may also be approached by the correlation technique; the product-moment correlation between wife's score and husband's estimate of it (i.e. sum of the husband's item estimates) is. 54 ± .03, and that between husband's score and wife's estimate of it is .40 ± .03. From these scatter diagrams we may also learn something about the relationships between estimate distributions and distributions of scores estimated; the mean of the wives' scores is higher than that of the husbands', a sex difference that is regularly found in this type of questionnaire (wives 74.3, husbands 61.8); both husbands and wives underestimated, the wives by a little more than the husbands (mean of the husbands' estimates 70.9, of the wives' 57.5). The variabilities of the estimates differ only insignificantly as between the sexes (standard deviations 21.2 for the husbands' estimates, 20.7 for the wives'), but both are somewhat greater than the variabilities of the distributions of the scores estimated (given above). Thus so far as spousal accuracy in general is concerned, it can be said that although errors in extreme cases are from a third to a half as great as it is possible for them to be in both directions, and although the distribution of errors has roughly as large a spread as has that of the total scores estimated, still the

average error is remarkably close to zero and the number of close correspondences substantial.

As to the relative efficiency of the sexes, no clear-cut result can be stated, since the scatter for wife's estimate vs. husband's score is both more heavily concentrated on the diagonal and more heavily weighted

TABLE 1

		WIFE'S ESTIMATE											
		10	20	30	40	50	60	70	80	90	100	110	120
Husband's score	110	..	..	..	..	..	..	..	..	..	2	..	..
	100	..	..	..	1	..	1	1	1	1	..	1	..
	90	..	..	1	1	2	..	2	2	2	1	..	..
	80	..	1	3	3	3	3	4	..	3	..	..	..
	70	..	..	3	5	11	8	10	7	2	1	1	1
	60	1	6	4	8	12	16	7	3	3	..	..	..
	50	..	2	5	17	12	7	7	1	..	1	..	..
	40	..	6	9	11	9	3	2	4	..	..	..	..
	30	..	1	8	3	3	2	1	1	..	..	..	1
	20	..	2	1	2	1	..	..	..	..	..	..	..
	10	..	..	..	1	..	..	..	..	..	..	..	..

TABLE 2

		HUSBAND'S ESTIMATE										
		20	30	40	50	60	70	80	90	100	110	120
Wife's score	140	..	..	..	..	..	..	..	..	1	..	..
	130	..	..	..	..	..	..	..	..	..	..	..
	120	..	..	..	1	..	..	..	1	1	..	..
	110	..	..	1	..	1	1	1	1	..	1	1
	100	..	..	..	..	1	5	3	6	2	1	2
	90	1	..	..	3	2	2	6	8	3	3	1
	80	1	..	1	6	8	11	4	9	..	1	1
	70	..	2	6	9	14	13	8	3	2	..	1
	60	..	1	7	15	5	9	10	3	..	..	..
	50	1	2	3	6	11	3	5	..	..	..	..
	40	1	2	7	2	3	3	1	1	..	..	..
	30	2	1	1	..	2	1	..	..	..	..	..
	20	..	..	1	1	..	..	..	..	..	..	..
	10	1	..	..	..	..	..	..	..	..	..	..

with distant outliers than the corresponding one for the husbands' estimates. The scatters are shown in Tables 1 and 2.

Thus while the numerical coefficient for the wives' efficiency is .14 lower than that for the husbands', the wives made 62 "hits" (on the diagonal) and 95 "grazes" (adjacent to the diagonal) as against only 46 hits but 104 grazes for the husbands. It may be noted that both sexes made estimates of this degree of closeness (average of 10 points difference or less) in over half of all cases (56 per cent and 58 per cent for husbands and wives respectively).

The results on accuracy of estimate for the individual items are very similar to those for total score; in this case, however, it must be kept in mind that since the number of categories is only five, there is a large probability that a correct prediction may be made by chance. The possible range of an item estimate error is 9 categories (0 plus four categories in each direction); in nearly all cases the obtained ranges extend to the full possibility of 9, and in all they reach at least 8; but the mean error in all cases falls within the 0 category. The great majority of the standard deviations lie between 1.0 and 1.5 categories. Accuracy on items may also be gauged by (1) coefficients of contingency between estimate and score, and (2) percentage of "hits" in the sense defined above; both of these are presented in Table 3 in detail, together with the abridged items.

With respect to *magnitude*, the percentage of hits has a median near 33, with half the items between 29 and 35 for the husbands and between 33 and 40 for the wives; the percentage of hits + grazes has a median at about 72, and half the items fall between 71 and 77; and the contingency coefficients have a median at .41, with half the items between .36 and .49. With respect to *sex differences*, there are more hit percentages above 50 among the wives than among the husbands (but the distributions for hits + grazes are about the same; there is a correlation of .57, however, between husbands and wives in the latter measure); the items in which one sex shows a clear superiority to the other are given in Table 4, with indication of the measure in which this is shown (for the hit measures 3 PF_d = approximately 5 per cent; for the contingency coefficients a difference of .10 has been taken as the criterion). The results are therefore ambiguous and depend largely on the measure used, but in general the wives appear to have a slight superiority. With respect to *item differences*, the high items in terms of hit scores are Nos. 1, 2, 10, 18, 33, and 38, to which must be added 25 and 30 on the basis

TABLE 3

ITEM	HUSBAND			WIFE		
	Hits (*percent*)	Hits + grazes (*percent*)	C with score	Hits (*percent*)	Hits + grazes (*percent*)	C with score
1 Difficulty making friends?	38	80	.41	39	81	.44
2 Watched on street?	45	81	.50	58	89	.13
3 Worry over humiliation?	28	71	.39	30	73	.56
4 Afraid of heights?	39	68	.55	39	69	.38
5 Feelings easily hurt?	28	73	.58	28	68	.27
6 Happy and sad by turns?	27	70	.34	35	75	.37
7 Daydream?	30	72	.44	35	74	.50
8 Discouraged easily?	32	73	.43	35	79	.47
9 Say things and regret them?	30	74	.40	27	72	.44
10 Cry easily?	34	79	.36	63	92	.41
11 Hurt when criticized?	27	74	.26	30	71	.56
12 Sometimes miserable?	28	73	.13	34	81	.47
13 Sometimes lonely?	34	75	.49	32	77	.20
14 Lack self-confidence?	35	78	.29	30	74	.49
15 Feel inferior?	36	78	.00	37	74	.38
16 Hard to make up mind?	31	72	.43	33	73	.41
17 Sometimes grouchy?	31	75	.36	31	72	.33
18 Sometimes remorseful?	31	78	.25	36	83	.42
19 Worry over possible misfortune?	34	75	.24	29	73	.33
20 Interests change quickly?	32	76	.32	36	78	.38
21 Prefer quiet amusements?	35	78	.52	34	76	.48
22 Avoid crowds?	32	73	.49	36	70	.49
23 Expression better in writing?	30	65	.39	35	72	.48
24 Like quiet vacations?	35	73	.47	35	74	.48
25 Act only after careful thought?	31	68	.70	38	77	.36
26 Prefer own sex?	34	77	.39	32	70	.28
27 Spend odd moments reading?	31	71	.38	33	66	.35
28 Nervous talking to audience?	39	77	.57	41	73	.56
29 Keep in background socially?	37	76	.51	29	70	.45
30 Shy?	38	77	.81	36	75	.86
31 Like to be alone?	32	73	.38	30	71	.32
32 Bothered to be watched?	31	66	.35	40	76	.37
33 Cross street to avoid meeting?	45	84	.52	59	87	.39
34 Avoid meeting people at tea?	38	73	.40	42	75	.44
35 Hesitate in group discussion?	38	75	.55	38	75	.42
36 Self-conscious with superiors?	30	72	.41	34	75	.42
37 Self-conscious over appearance?	31	63	.34	30	70	.19
38 Avoid helping in accident?	45	78	.55	47	81	.53
39 Upset when people crowd?	30	68	.47	34	70	.48
40 Stand or leave when late?	35	70	.50	32	65	.38

TABLE 4

ITEM	HUSBAND SUPERIOR			WIFE SUPERIOR		
	Hits	H + G	C	Hits	H + G	C
2	..	..	×	×	×	..
3	..	..	..	..	..	×
4	..	..	×	..	..	..
5	..	..	×	..	..	..
6	..	..	..	×	×	..
8	..	..	..	..	×	..
10	..	..	..	×	×	..
11	..	..	..	..	..	×
12	..	..	..	×	×	×
13	..	..	×	..	..	..
14	..	..	..	..	..	×
15	..	..	..	..	..	×
18	..	..	..	..	..	×
23	..	..	..	..	×	..
25	..	..	×	×	×	..
26	..	×	×	..	..	..
29	×	×	..	..	..	..
32	..	..	..	×	×	..
33	..	..	×	×	..	..
35	..	..	×	..	..	..
37	..	×	..	..	..	×
40	..	..	×	..	..	..

of the contingency measures; the low ones in hit scores are 4, 23, 37, 39, and 40, and in contingency (at least for one sex) 2, 12, 13, 15, and 37; the differentiating factor here, as might be expected, appears to be the amount of overt action involved—those reactions which are most implicit being those most difficult to estimate.

The correlation in estimating efficiency between husband and wife (homogamy) is also of interest. Using the total estimate error as the most representative variable, the product-moment coefficient is —.32

± .04, which after partialling out the estimated scores concerned becomes —.24; so far as the writer knows this is the first negative homogamy coefficient of significant size to be reported, and its significance is difficult to conjecture. Breakdown into item homogamies shows that it is not the result of any artifact; only three of the items have positive coefficients, and of these only one (*Do you sometimes feel grouchy?*) is significantly so. The coefficients in order are as follows:

—.12	—.21	—.05	.00	—.03	—.16	—.19	—.18	—.06	—.14
—.11	—.23	—.13	—.02	—.12	+.05	+.21	—.17	—.12	—.06
—.09	—.13	—.04	—.08	—.18	—.15	—.01	—.04	—.13	—.13
.00	—.20	—.04	—.26	—.05	+.03	—.25	—.11	—.24	—.31

The median of these coefficients is at —.12, the range from —.31 to +.21, and the middle half lie between —.17 and —.06. We are accordingly forced to conclude that (to this slight extent) men who overestimate are married to women who underestimate, and men who underestimate to women who overestimate.

The cross and partial correlations computed in partialling out score effects from the total-score homogamy coefficient mentioned above are interesting in their own right. The wife's estimate error correlates with her own score .10 ± .04, and the husband's estimate error with his own score .13 ± .04; these become .20 and .24 when the spouse's score (which is being estimated) is held constant. Thus it appears that a higher score in the estimator tends to produce an algebraically higher estimate error—i.e. neuroticism in the estimator goes with a tendency to see more neuroticism than there "is" in his spouse—but the variation in the score estimated tends to reduce this; these tendencies, however, are all slight. The husband's estimate error correlates —.45 ± .03 with the wife's score which he is estimating, and the wife's estimate error correlates —.42 ± .03 with the husband's score; these become —.48 and —.45 respectively when the estimator's own score is held constant. These coefficients are substantial for this field of inquiry, and appear to mean that both spouses tend to compensate, or move their estimates toward the population norm, in estimating their spouses' responses; and since the standard deviations of the resulting estimates are not less than those of the scores estimated, it seems to follow that both spouses must

tend to overcompensate, or move the estimates beyond the population norm.

We should naturally like to know whether the estimate error is related to the satisfaction in marriage of either the estimator or the estimatee; unfortunately, however, the satisfaction scores are so massed at the "4" (satisfied) end of the scale that no adequate information can be obtained (198 husbands and 208 wives of the total of 271 couples report "4" as to satisfaction with the marriage as a whole, and 49 husbands and 44 wives report "3"). In none of the scatters, however (wife's total estimate error vs. own satisfaction and vs. husband's satisfaction, husband's estimate error vs. own satisfaction and vs. wife's satisfaction) was the total-estimate-error median for any of the satisfaction-score arrays significantly different from zero. There is thus no evidence that satisfaction with the marriage has any influence on estimation accuracy, and some evidence that it does not.

The duration of marriage also, somewhat surprisingly, seems to have no systematic effect upon accuracy of estimation. The total group was divided into 9 duration groups of roughly equal size (but therefore of unequal duration units), and the total estimate errors of each sex were distributed inside these; the medians of these estimate-error distributions showed no systematic trend in either sex, and were close to zero in both. For items 1-8 the medians also showed no trend with increasing duration, and remained near zero throughout; a few of the variability curves showed slight declines with increasing duration and some showed equally slight rises, but none showed clearly significant trends; the sole positive result was that in the longer duration groups (over about 15 years) the women were regularly less variable than the men.

Results are also negative with respect to the effects of number of children upon estimate accuracy; age is, of course, highly correlated with duration of marriage and therefore presumably negative as to influence as well. There is no reason to anticipate any effect from occupational or educational status, since these have been found in other investigations to have little relationship to score.

In summary, this evaluation has shown that spouses have substantial though not high accuracy in predicting each other's responses in this type of inventory; whether superior efficiency lies with the male or with the females seems to depend largely on the method of evaluation, although there is some probability in favor of the female. There is a

true negative homogamic correlation in estimate error, although it is of small magnitude; it appears to indicate a tendency, with unknown determinants, for spouses who tend to overestimate to be married to spouses who tend to underestimate. There is a small positive correlation between the estimator's estimate error and his own score, suggesting something like a projection mechanism; and a fairly high negative correlation between estimate error and score estimated, apparently indicating a tendency to estimate nearer the mean of the population than the true score lies, and even to cross this mean. Satisfaction with the marriage, duration of marriage, number of children, and presumably age, education, and occupation have no demonstrable effect upon accuracy of estimate.

RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

I. EVOLUTION AND GENETICS

1. *Evolution—General Principles*

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